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Hiraiwa et al.

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(54) **COMPUTER SYSTEM AND CONTROL METHOD FOR THE COMPUTER SYSTEM**

(75) Inventors: **Yuri Hiraiwa**, Sagamihara (JP);
Nobuhiro Maki, Yokohama (JP);
Takeyuki Imazu, Yokohama (JP)

(73) Assignee: **Hitachi, Ltd.**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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US 2011/0202738 A1 Aug. 18, 2011

Related U.S. Application Data

(63) Continuation of application No. 12/877,217, filed on Sep. 8, 2010, now Pat. No. 7,958,306, which is a continuation of application No. 12/366,685, filed on Feb. 6, 2009, now Pat. No. 7,809,887, which is a continuation of application No. 11/486,160, filed on Jul. 14, 2006, now Pat. No. 7,512,757.

(30) **Foreign Application Priority Data**

Apr. 26, 2006 (JP) 2006-121541

(51) **Int. Cl.**
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G06F 11/00 (2006.01)

(52) **U.S. Cl.** **711/114**; 711/161; 711/162; 714/6.11; 714/20

(58) **Field of Classification Search** 711/114, 711/161, 162; 714/6, 20, 6.11
See application file for complete search history.

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Primary Examiner — Kevin Ellis

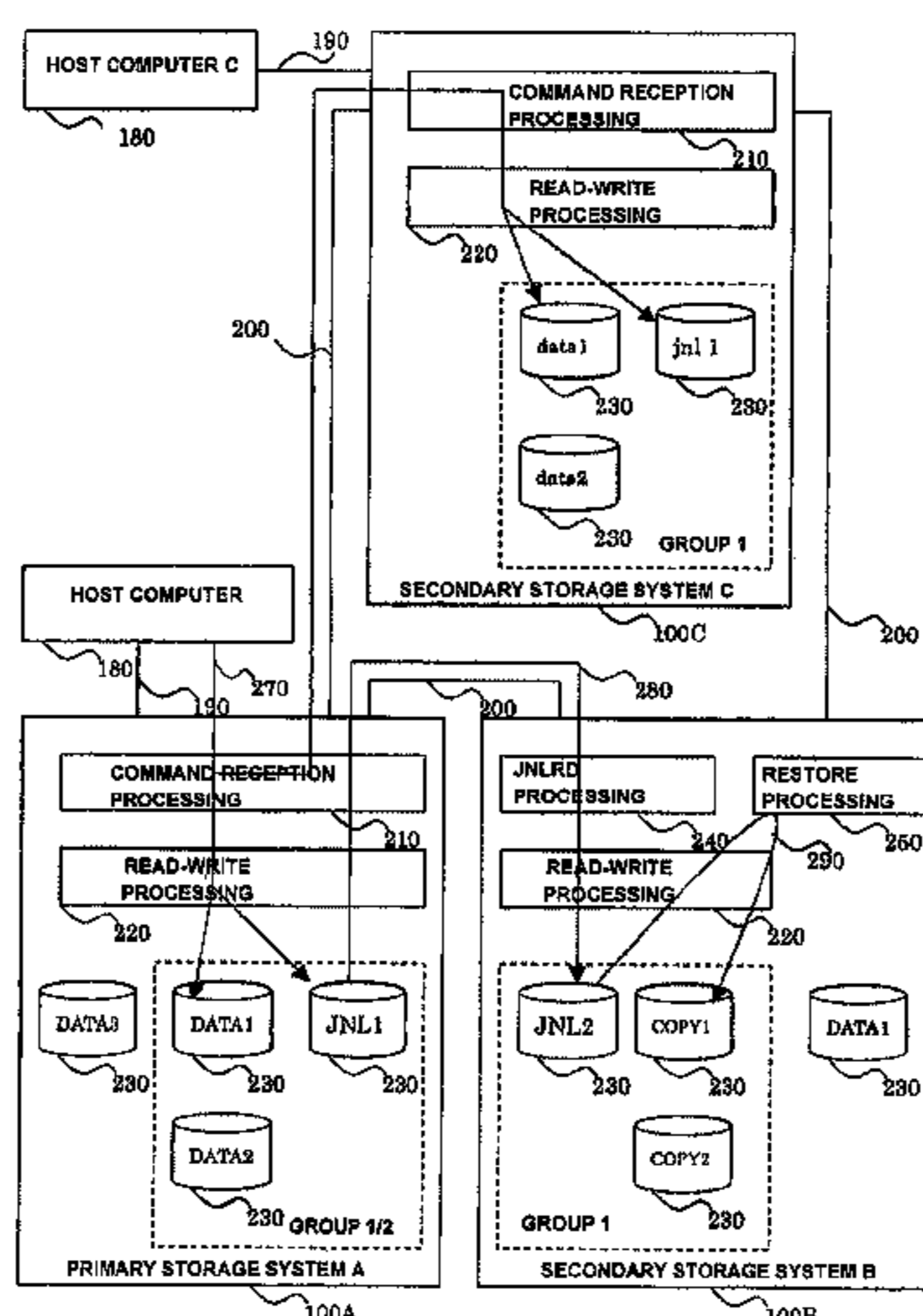
Assistant Examiner — Mehdi Namazi

(74) *Attorney, Agent, or Firm* — Brundidge & Stanger, P.C.

(57) **ABSTRACT**

A computer system including a first storage system connected to a first host computer, a second storage system connected to a second host computer and a third storage system connected to the first and second storage systems. The second storage system sets transfer setting before an occurrence of a failure, the transfer setting being provided with a dedicated storage area to be used for transferring data to the third storage system by asynchronous copy in response to a failure at the first host computer. Before the start of data transfer between the second storage system and third storage system to be executed after an occurrence of the failure, the second storage system checks the dedicated storage area, data transfer line and transfer setting information, and if an abnormal state is detected, this abnormal state is reported to the host computer as information attached to the transfer setting.

18 Claims, 35 Drawing Sheets



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FIG. 1

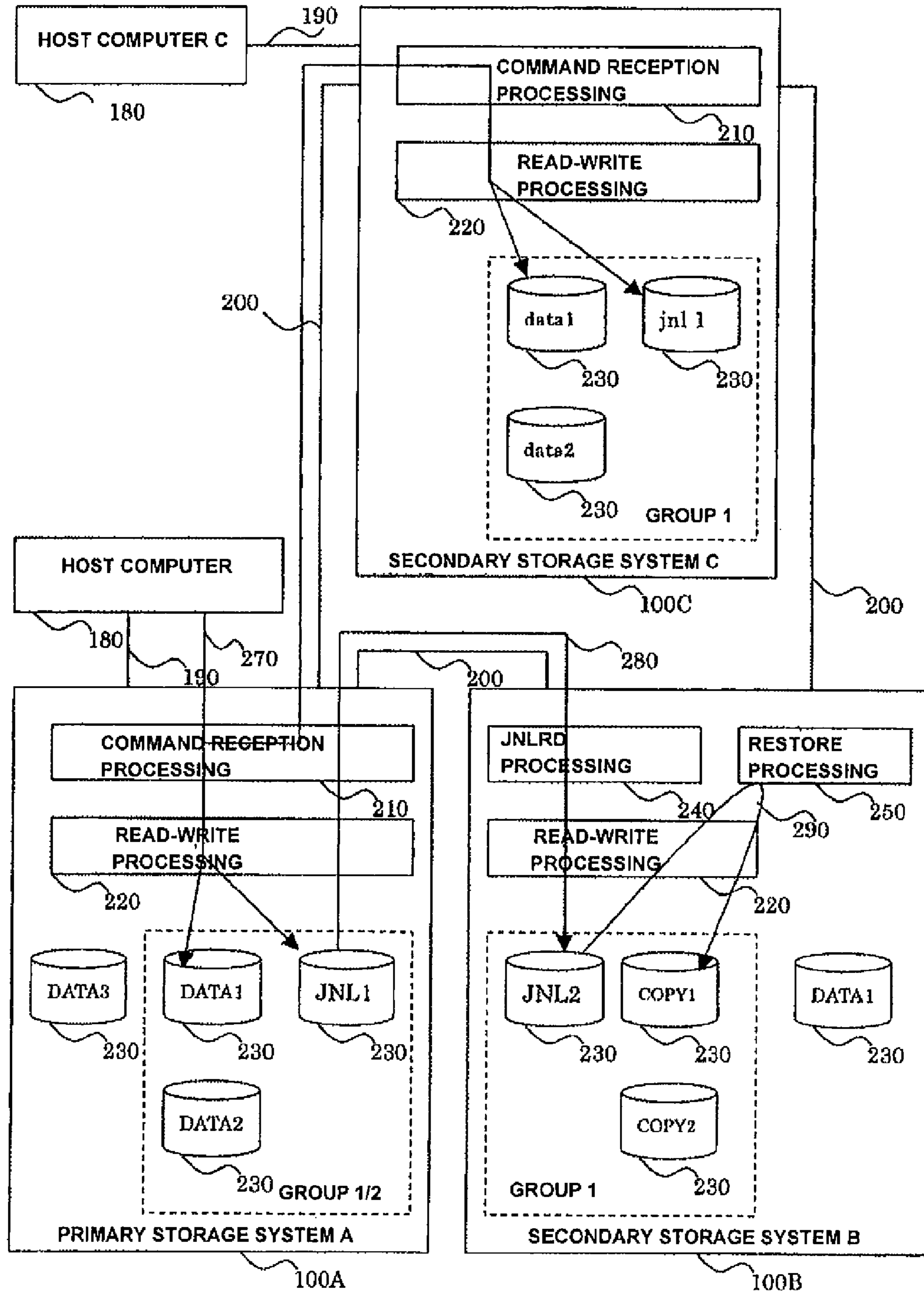


FIG. 2

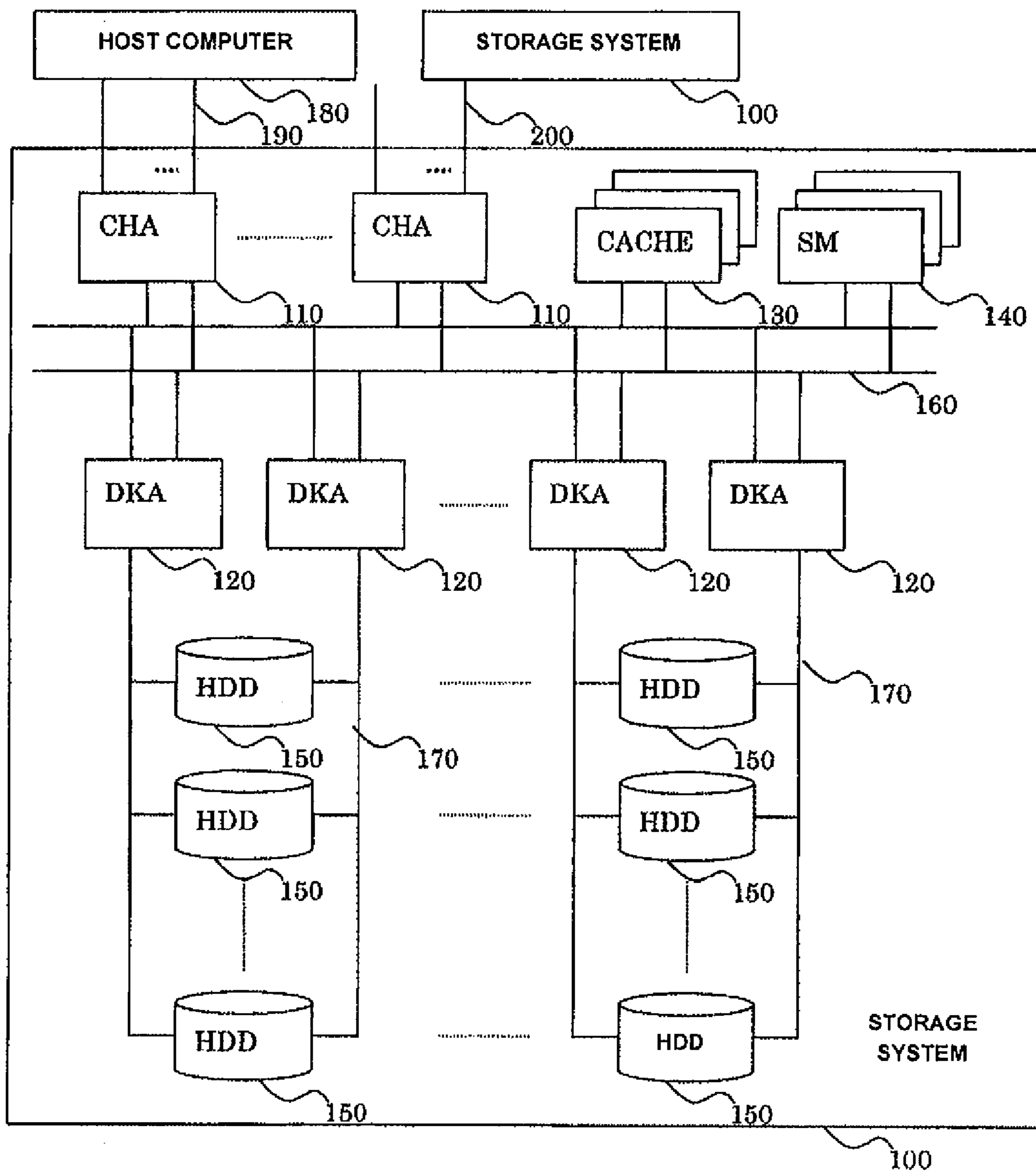


FIG. 3

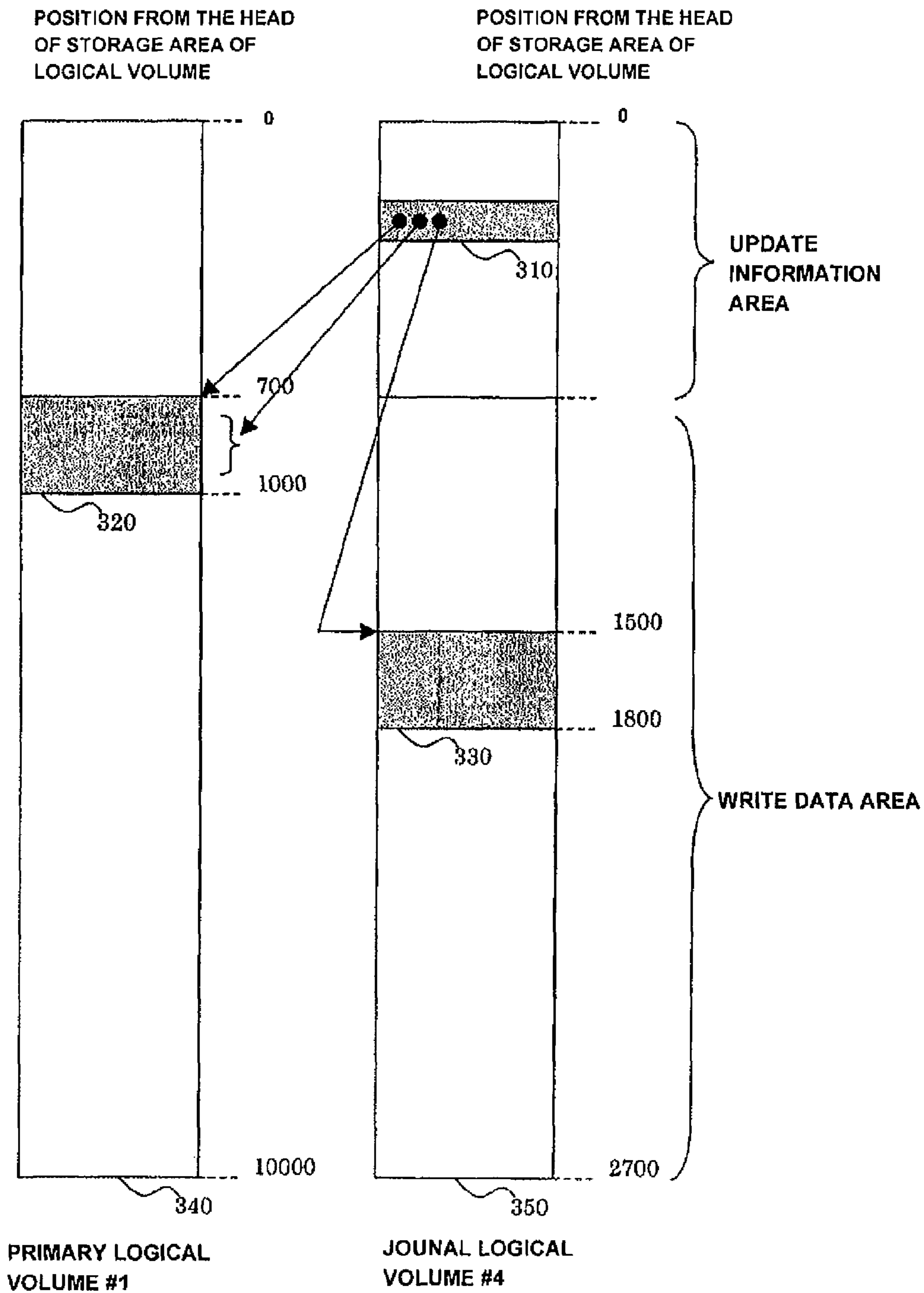


FIG. 4

LOGICAL VOLUME NUMBER	VOLUME STATE	FORMAT	CAPACITY	SYNC PAIR NUMBER	ASYNC PAIR NUMBER	PHYSICAL ADDRESS	
						STORAGE DEVICE NUMBER	POSITION FROM THE HEAD
1	PRIMARY	OPEN3	3	3	1	1	0
2	PRIMARY	OPEN6	6	4	2	1	3
3	BLANK	OPEN6	6	0	0	1	9
4	NORMAL	OPEN9	9	0	0	2	0
5	NORMAL	OPEN3	3	0	0	2	9
6	BLANK	OPEN6	6	0	0	2	12

400 VOLUME INFORMATION

FIG. 5

PAIR NUMBER	PAIR STATE	PRIMARY STORAGE SYSTEM NUMBER	PRIMARY LOGICAL VOLUME NUMBER	SECONDARY STORAGE SYSTEM NUMBER	SECONDARY LOGICAL VOLUME NUMBER	GROUP NUMBER	COPY COMPLETED ADDRESS
1	NORMAL	A	1	B	1	1	0
2	NORMAL	A	2	B	2	1	0
3	NORMAL	A	1	C	1	2	0
4	NORMAL	A	2	C	2	2	0
5	BLANK	0	0	0	0	0	0

500 PAIR INFORMATION

FIG. 6

GROUP NUMBER	GROUP STATE	PAIR SET	JOURNAL LOGICAL VOLUME NUMBER	UPDATE NUMBER	REPLICATION TYPE	PARTNER STORAGE SYSTEM NUMBER	PARTNER GROUP NUMBER	
1	NORMAL	1,2	3	5	ASync	B	2	0
2	NORMAL	3,4	3	1	Sync	C	2	1

}
600 GROUP INFORMATION

FIG. 7

	LOGICAL ADDRESS	
	LOGICAL VOLUME NUMBER	POSITION FROM THE HEAD OF STORAGE AREA OF LOGICAL
UPDATE INFORMATION AREA HEAD ADDRESS	4	0
WRITE DATA AREA HEAD ADDRESS	4	700
UPDATE INFORMATION LATEST ADDRESS	4	500
UPDATE INFORMATION OLDEST ADDRESS	4	200
WRITE DATA LATEST ADDRESS	4	2200
WRITE DATA OLDEST ADDRESS	4	1300
READ INITIATION ADDRESS	4	400
RETRY INITIATION ADDRESS	4	300

700 POINTER INFORMATION

FIG. 8

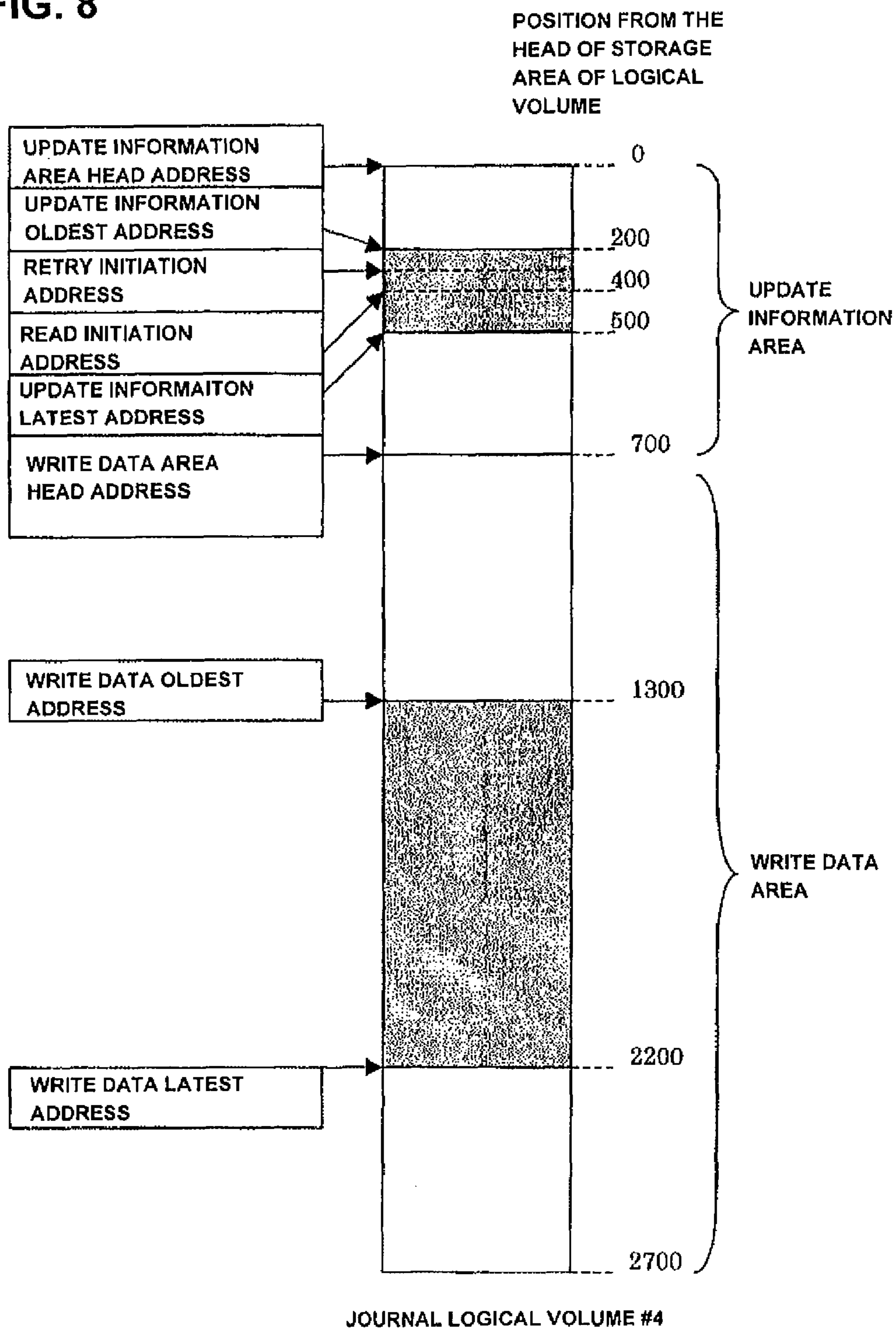


FIG. 9

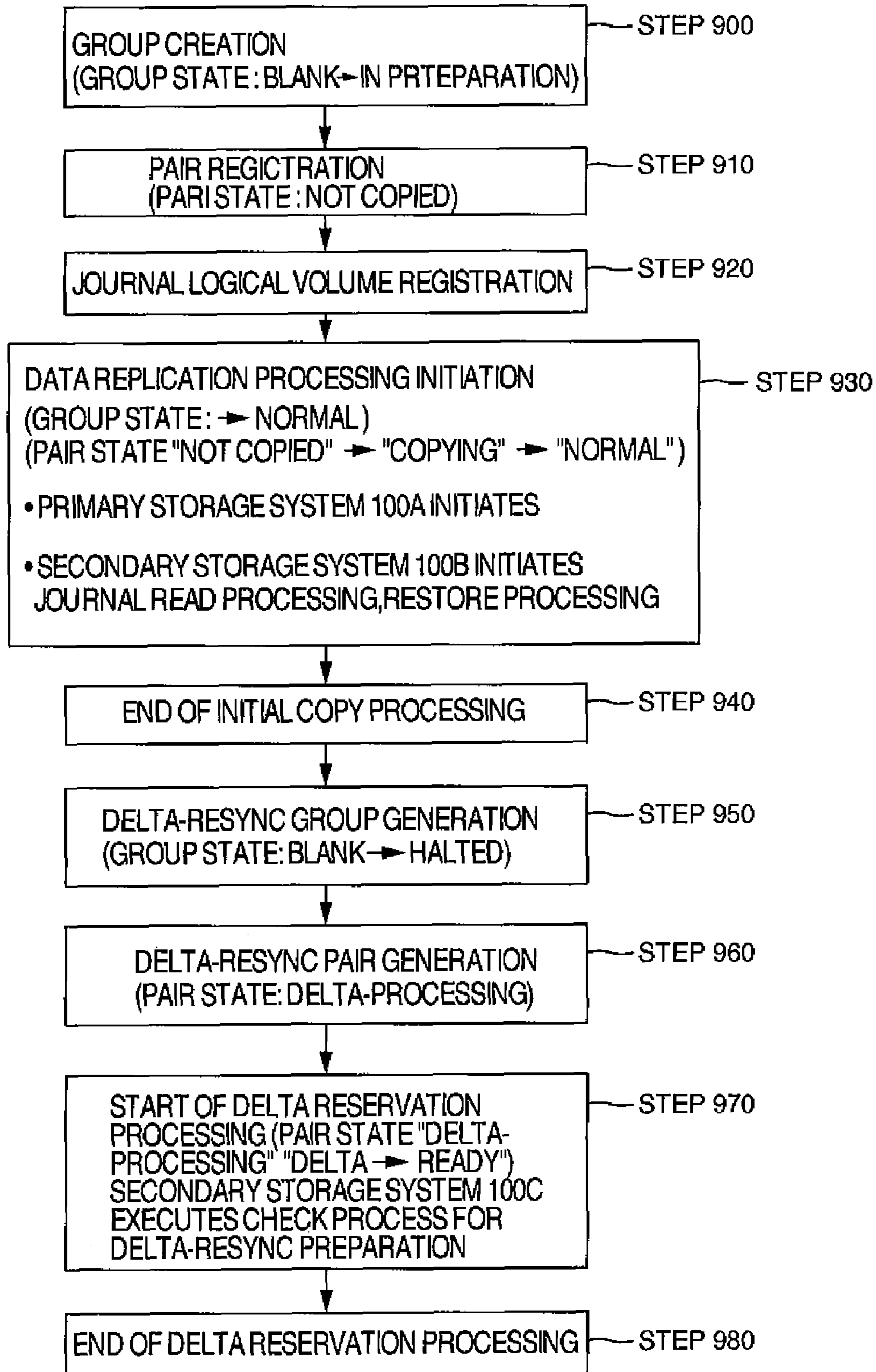


FIG. 10

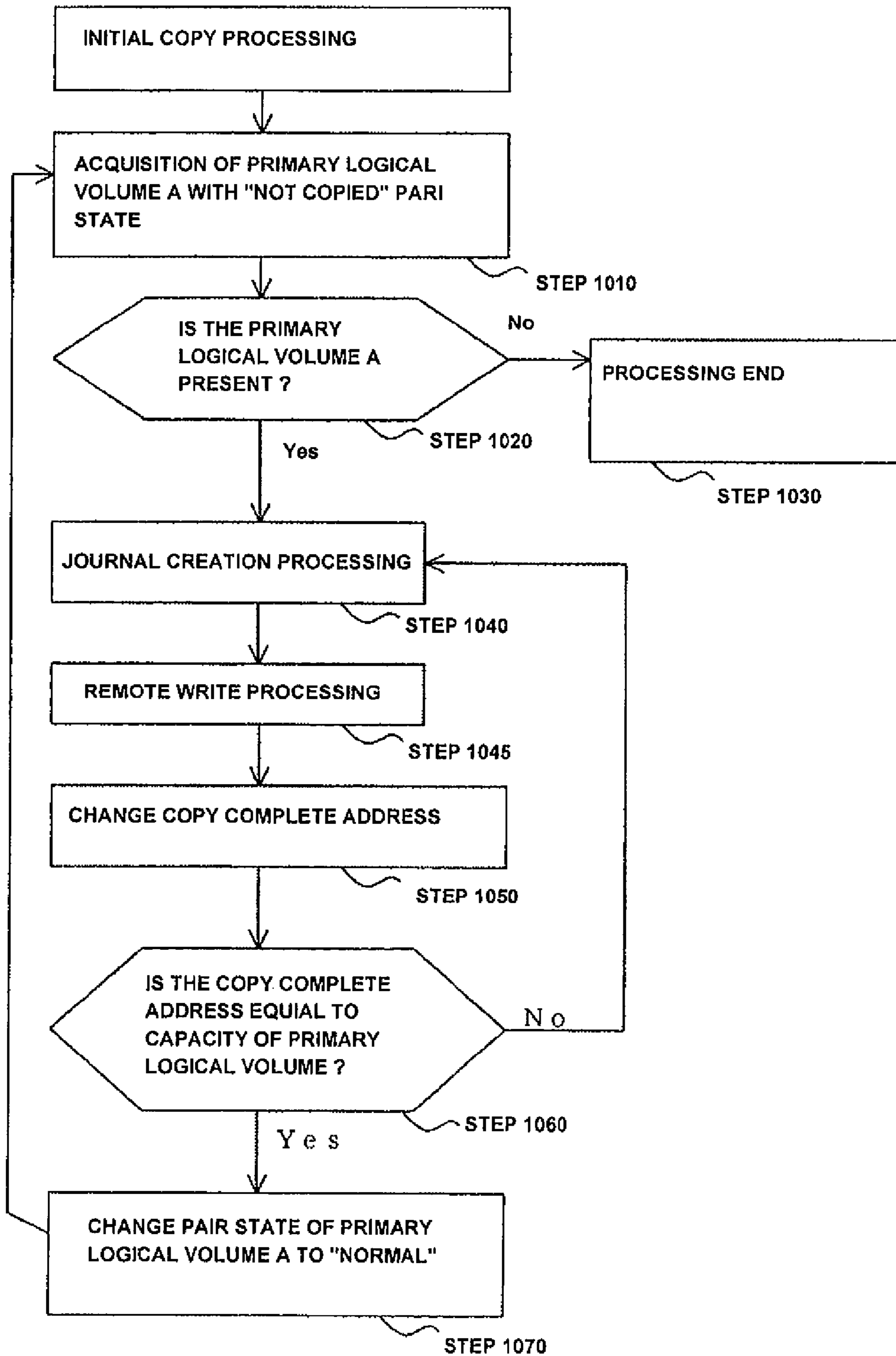


FIG. 11

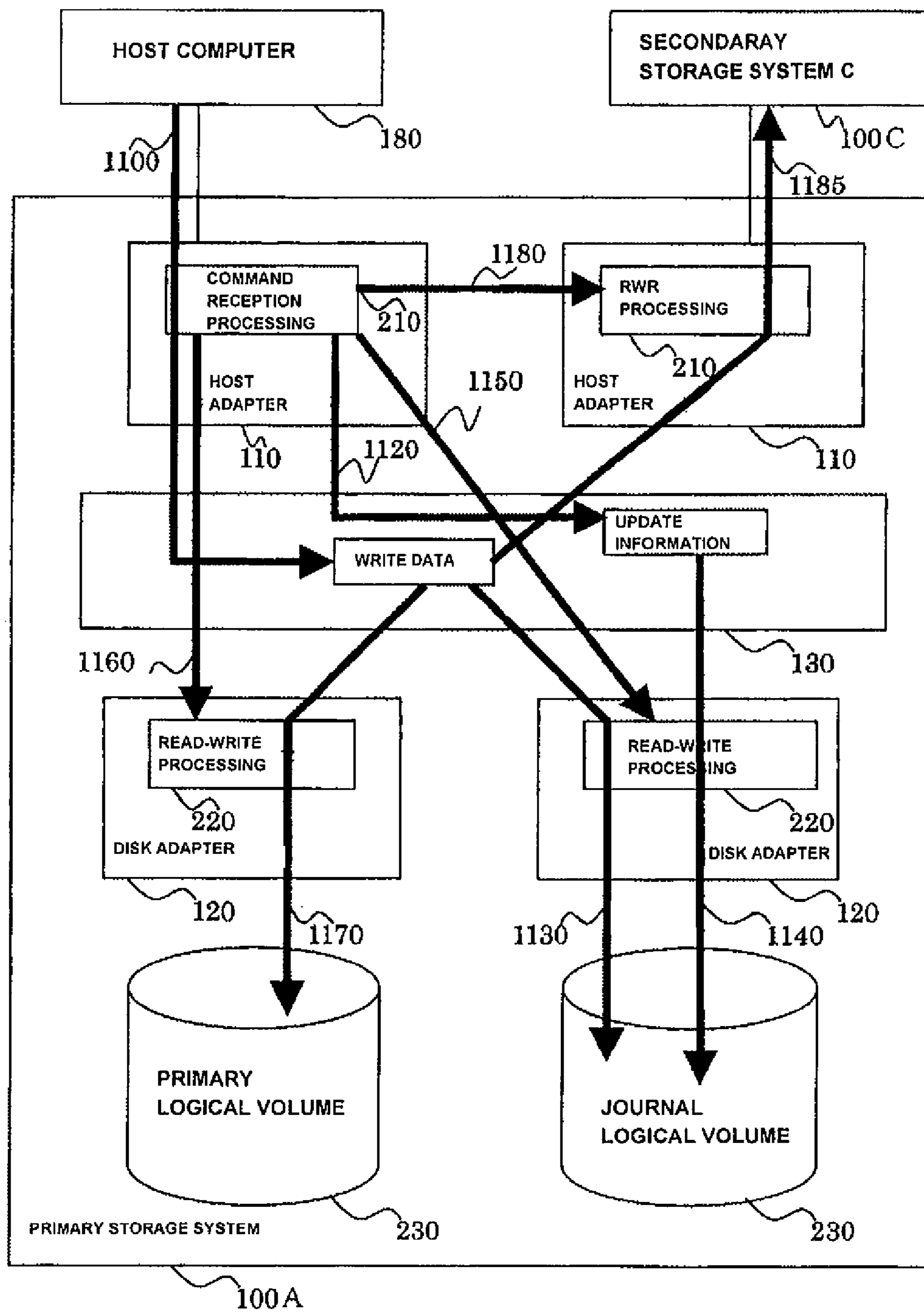


FIG. 12

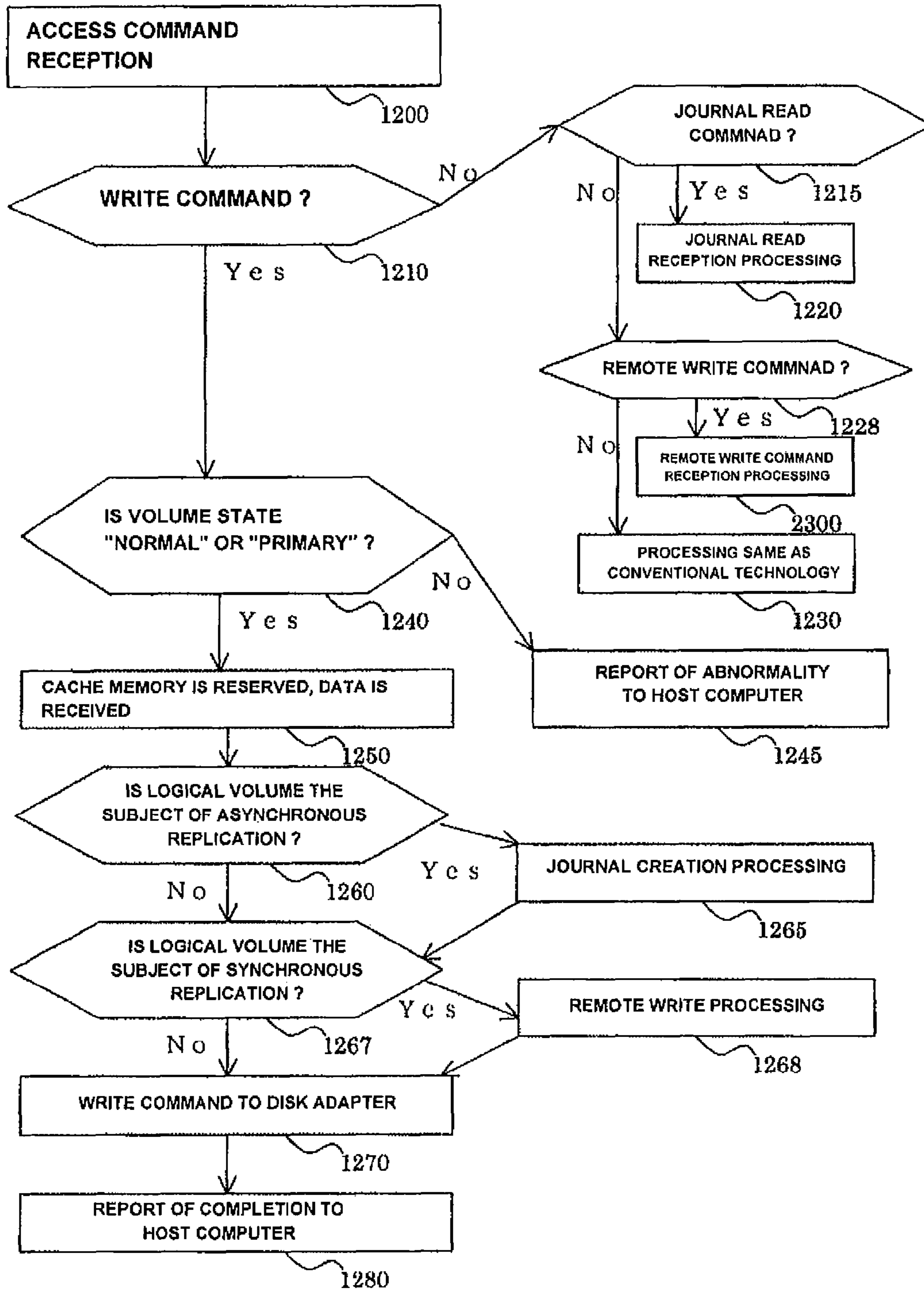


FIG. 13

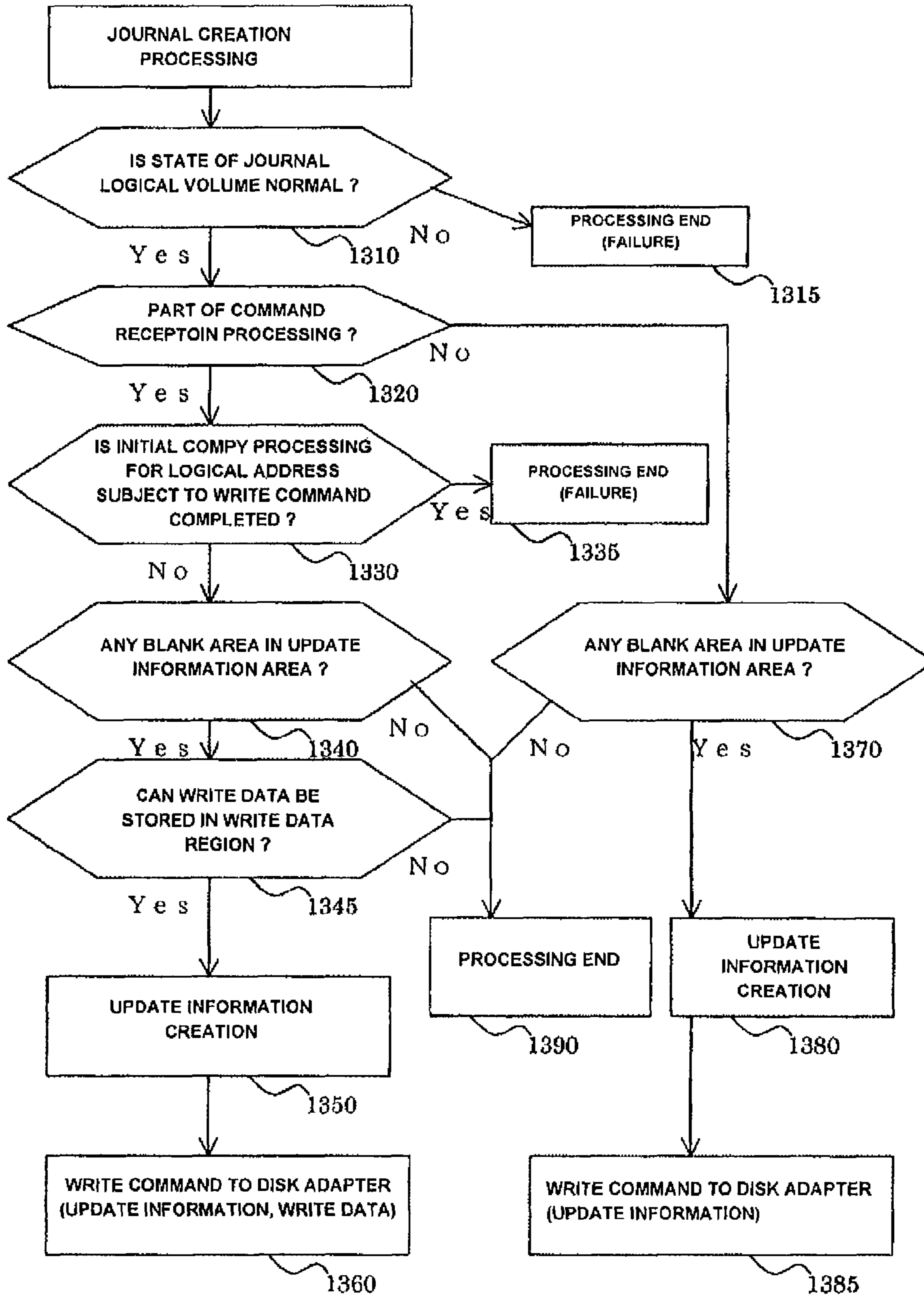


FIG. 14

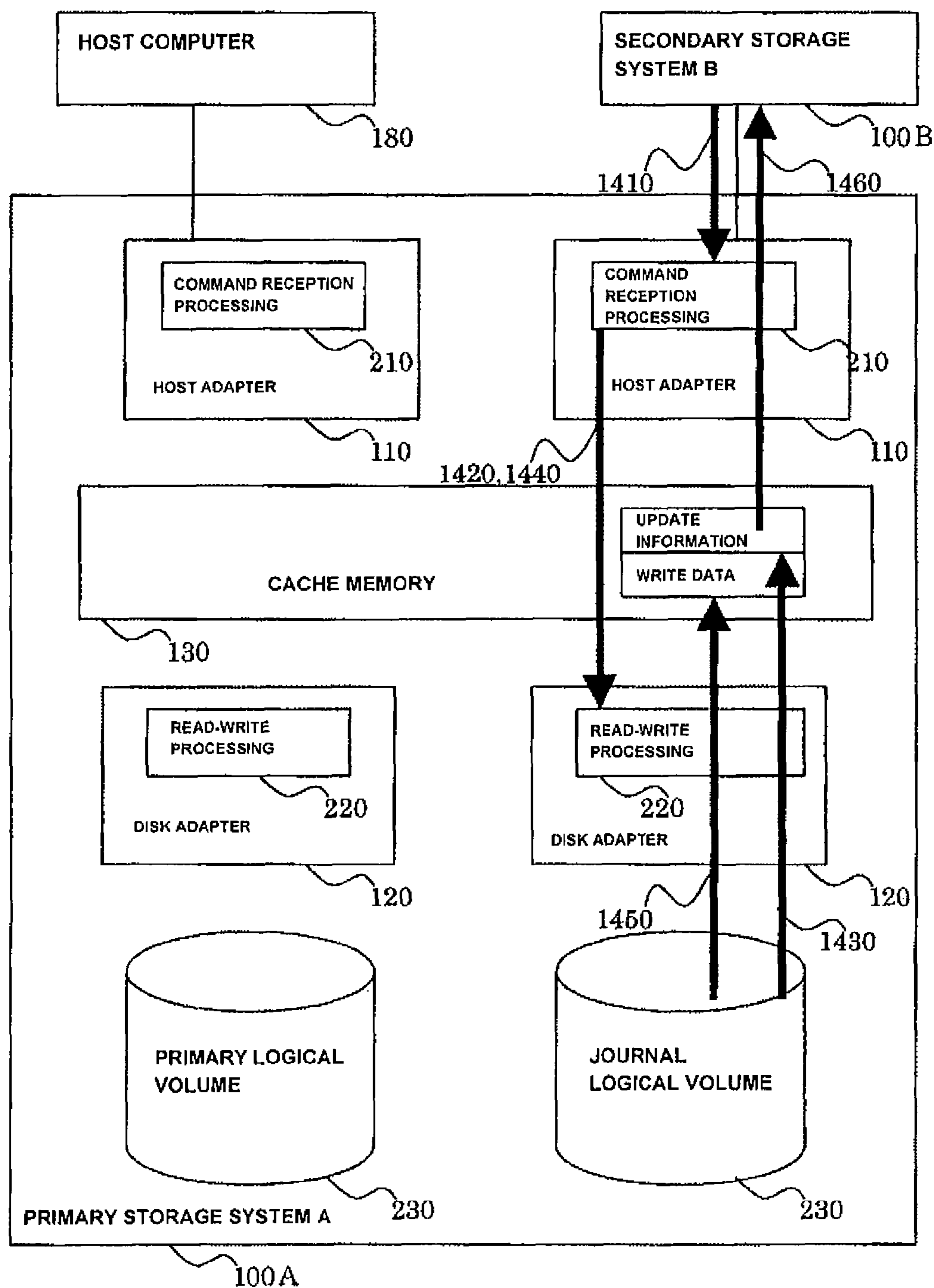


FIG. 15

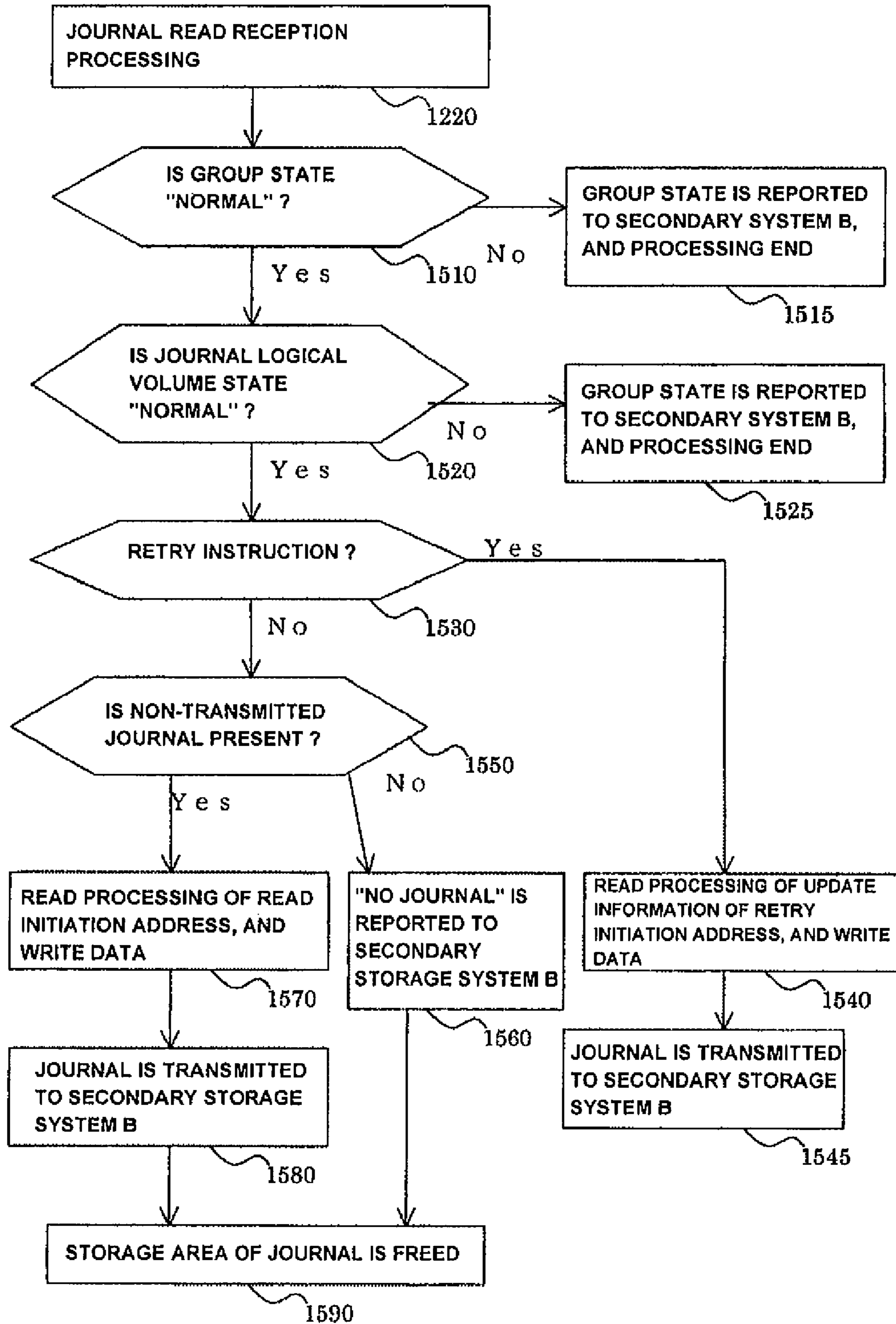


FIG. 16

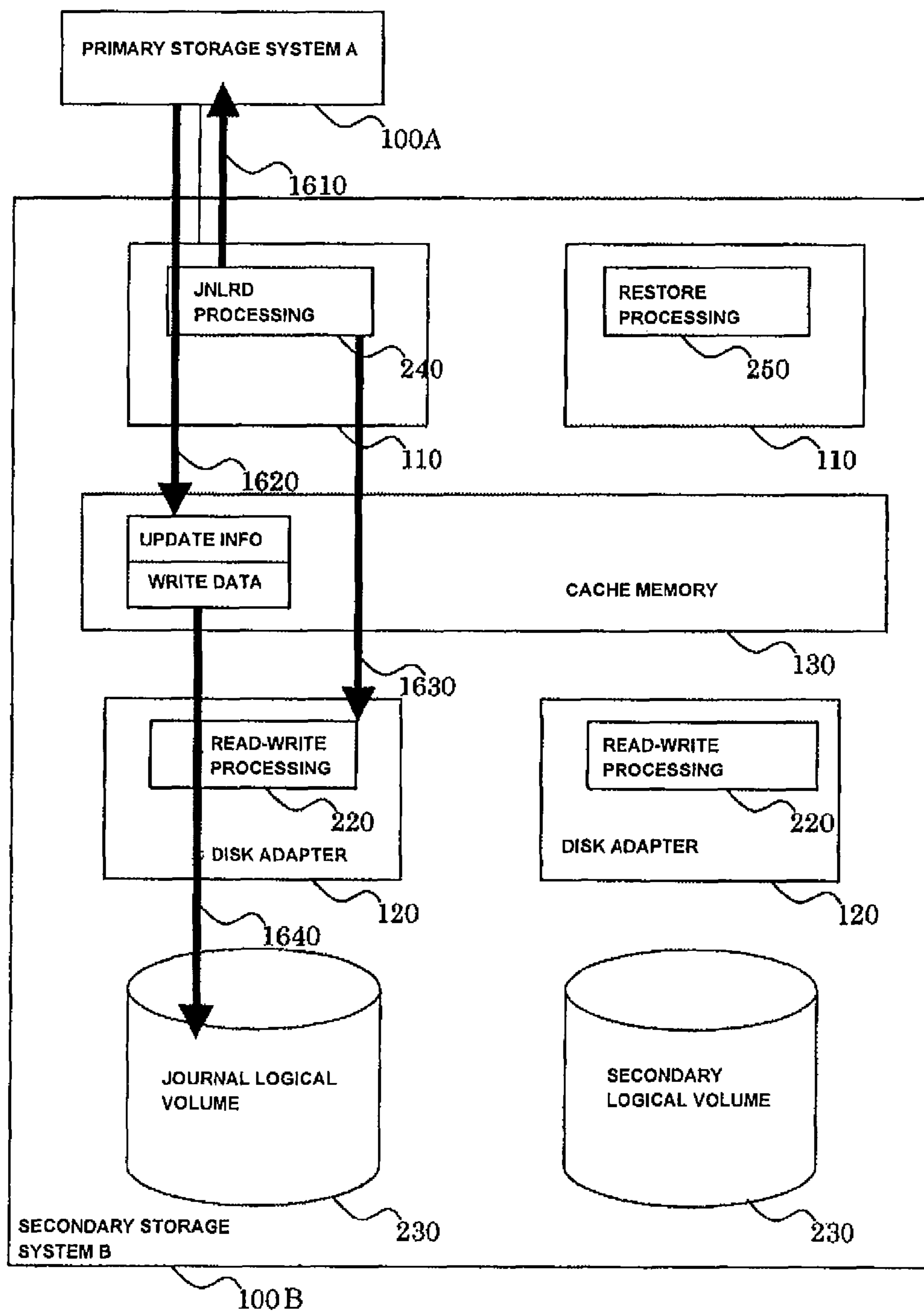


FIG. 17

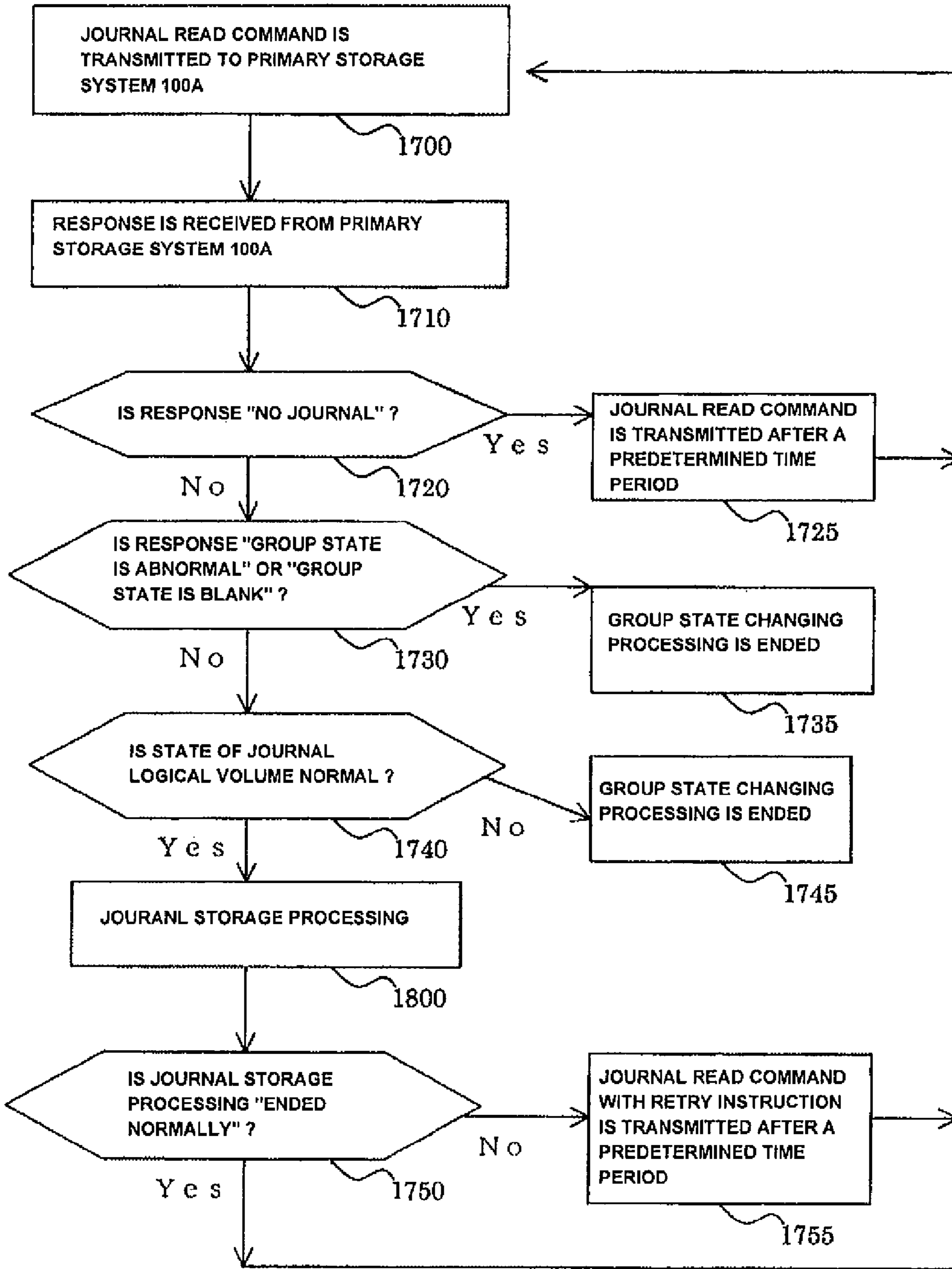


FIG. 18

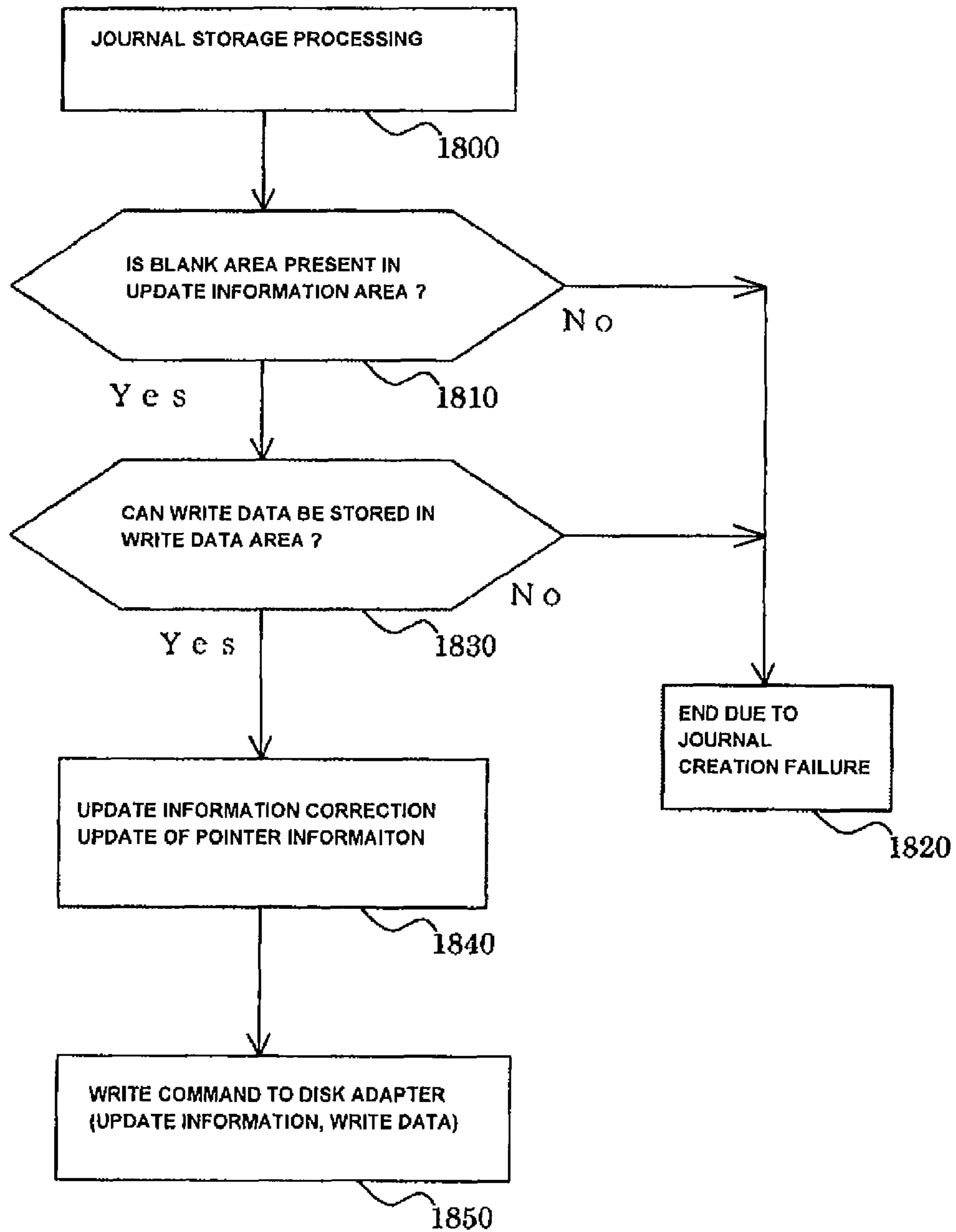


FIG. 19

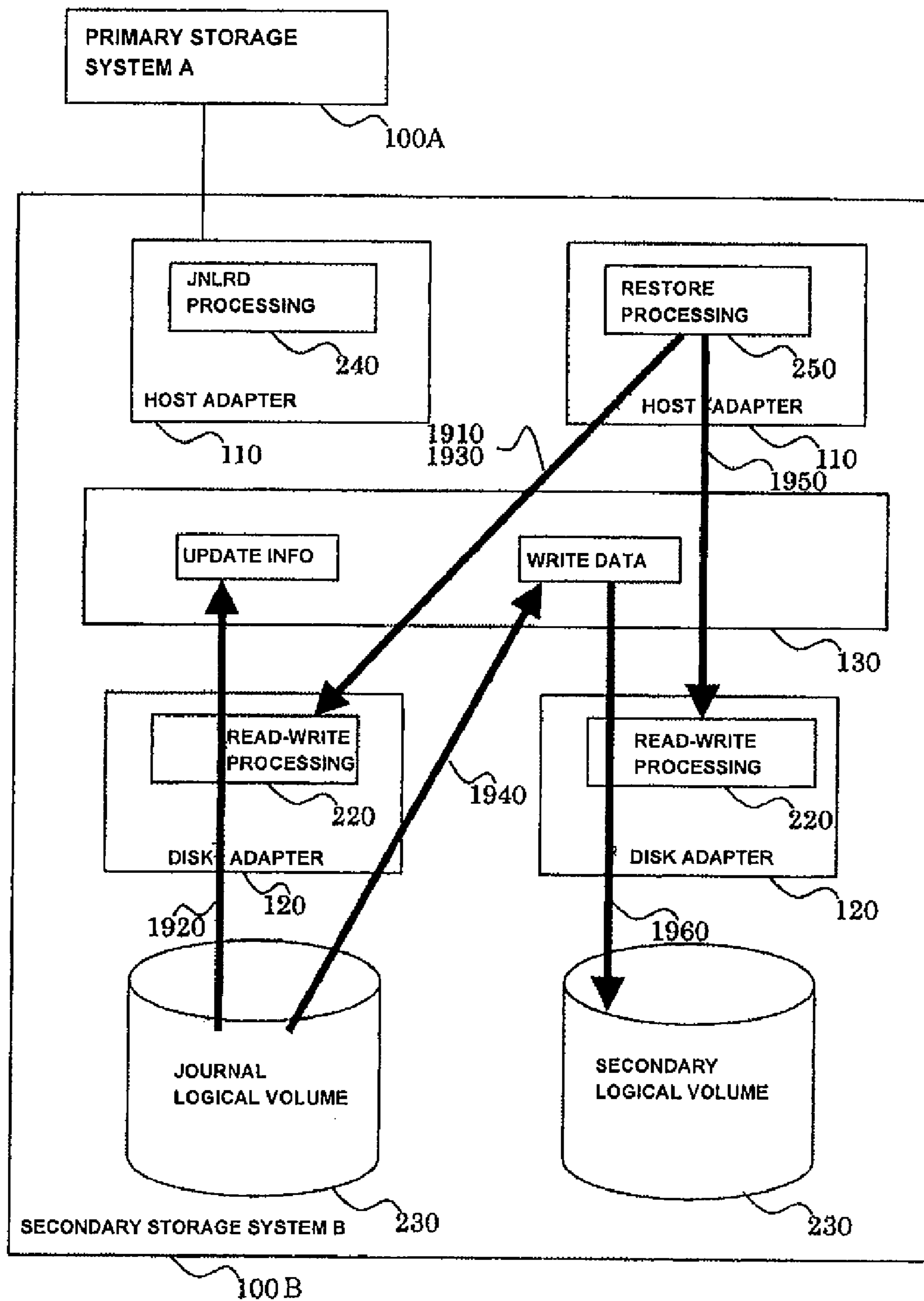


FIG. 20

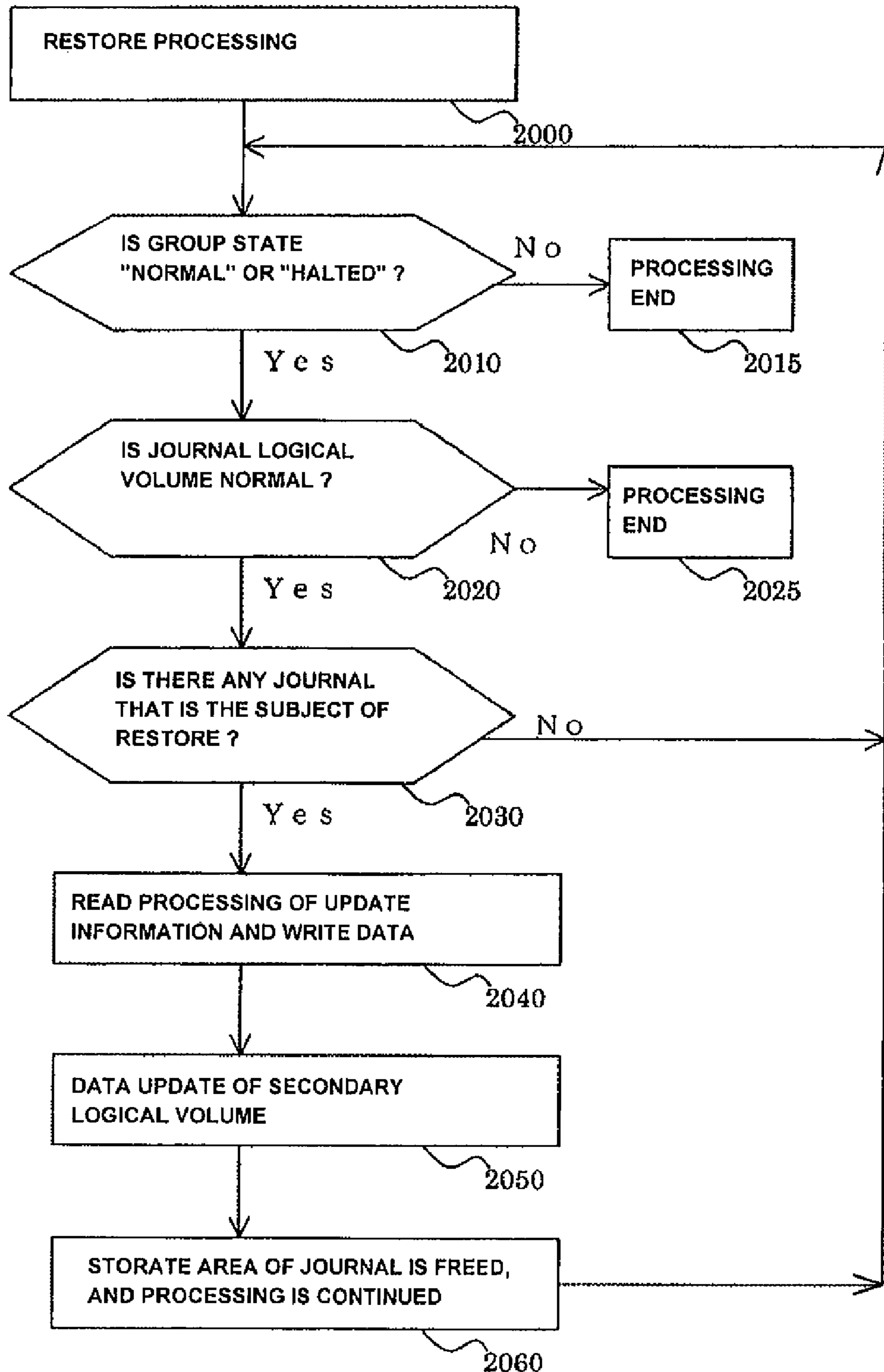


FIG. 21

SETTING ITEMS	EXAMPLE OF SET VALUES
TIME WHEN WRITE COMMAND IS RECEIVED	1999/3/17 22:20:10
GROUP NUMBER	1
UPDATE NUMBER	4
LOGICAL ADDRESS OF WRITE COMMAND	LOGICAL VOLUME NUMBER: 1 POSITION FROM HEAD OF STORAGE AREA OF LOGICAL VOLUME : 700
DATA SIZE OF WRITE DATA	300
LOGICAL ADDRESS OF JOURNAL LOGICAL VOLUME THAT STORES WRITE DATA	LOGICAL VOLUME NUMBER: 4 POSITION FROM HEAD OF STORAGE AREA OF LOGICAL VOLUME : 1500

310 UPDATE INFORMATION

FIG. 22

SETTING ITEMS	EXAMPLE OF SET VALUES
TIME WHEN WRITE COMMAND IS RECEIVED	1999/3/17 22:22:10
GROUP NUMBER	1
UPDATE NUMBER	5
LOGICAL ADDRESS OF WRITE COMMAND	LOGICAL VOLUME NUMBER: 1 POSITION FROM HEAD OF STORAGE AREA OF LOGICAL VOLUME : 800
DATA SIZE OF WRITE DATA	100
LOGICAL ADDRESS OF JOURNAL LOGICAL VOLUME THAT STORES WRITE DATA	LOGICAL VOLUME NUMBER: 4 POSITION FROM HEAD OF STORAGE AREA OF LOGICAL VOLUME : 2200

FIG. 23

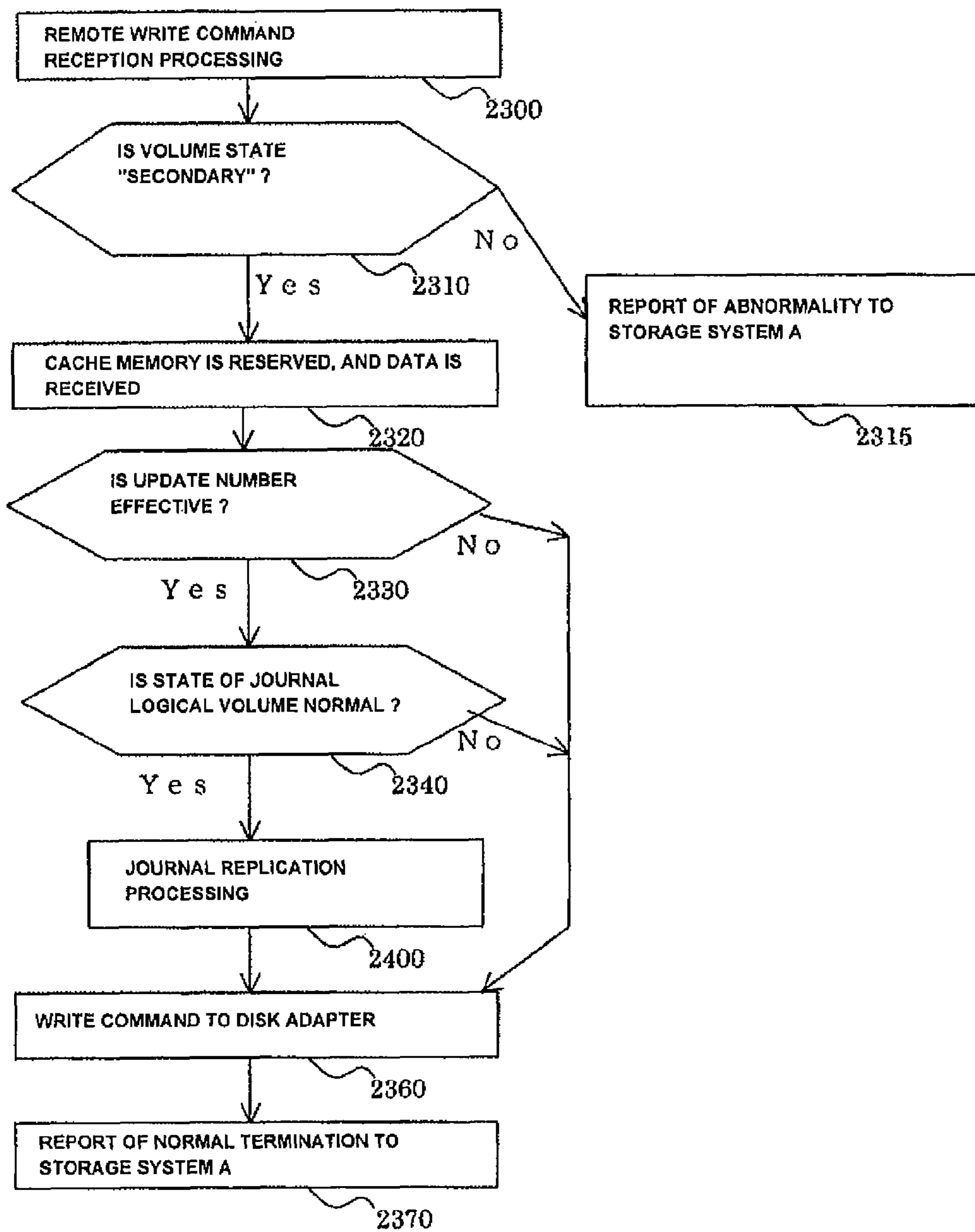


FIG. 24

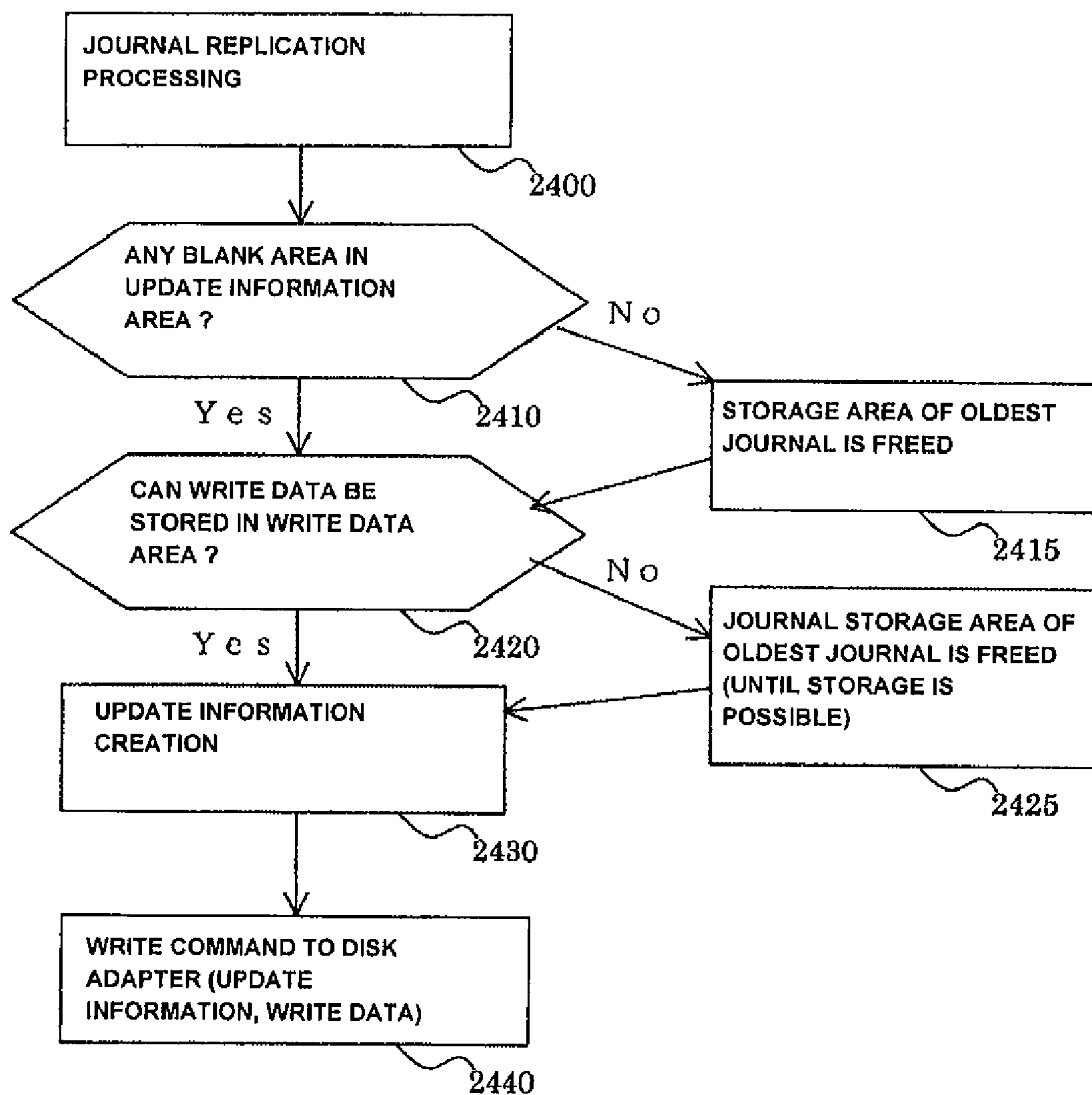


FIG. 25

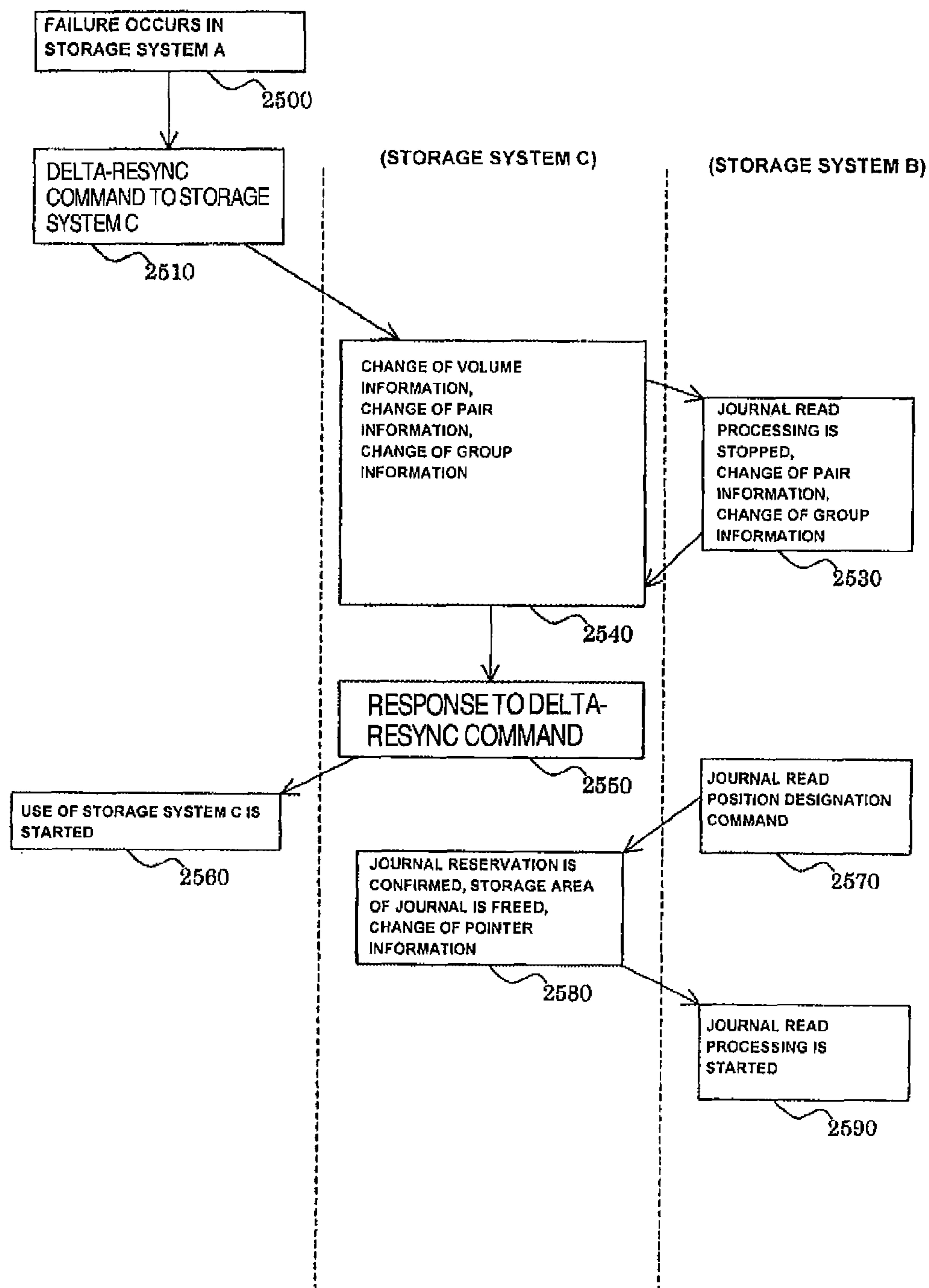


FIG. 26

LOGICAL VOLUME NUMBER	VOLUME STATE	FORMAT	CAPACITY	SYNC PAIR NUMBER	ASYNC PAIR NUMBER	PHYSICAL ADDRESS	
						STORAGE DEVICE NUMBER	POSITION FROM THE HEAD
1	SECONDARY	OPEN3	3	0	1	1	0
2	SECONDARY	OPEN6	6	0	2	1	3
3	NORMAL	OPEN9	9	0	0	2	0

FIG. 27

PAIR NUMBER	PAIR STATE	PRIMARY STORAGE SYSTEM NUMBER	PRIMARY LOGICAL VOLUME NUMBER	SECONDARY STORAGE SYSTEM NUMBER	SECONDARY LOGICAL VOLUME NUMBER	GROUP NUMBER	COPY COMPLETED ADDRESS
1	NORMAL	A	1	B	1	1	0
2	NORMAL	A	2	B	2	1	0
3	DELTA-READY	C	1	B	1	2	0
4	DELTA-READY	C	2	B	2	2	0

FIG. 28

GROUP NUMBER	GROUP STATE	PAIR SET	JOURNAL LOGICAL VOLUME NUMBER	UPDATE NUMBER	REPLICATION TYPE	PARTNER STORAGE SYSTEM NUMBER	PARTNER GROUP NUMBER	DELTA RESERVATION OPTION
1	NORMAL	1,2	3	4	ASYNC	A	1	0
2	STOP	3,4	3	0	ASYNC	C	2	1

FIG. 29

	LOGICAL ADDRESS	
	LOGICAL VOLUME NUMBER	POSITION FROM THE HEAD OF STORAGE AREA OF LOGICAL VOLUME
UPDATE INFORMATION AREA HEAD ADDRESS	3	0
WRITE DATA AREA HEAD ADDRESS	3	700
UPDATE INFORMATION LATEST ADDRESS	3	400
UPDATE INFORMATION OLDEST ADDRESS	3	200
WRITE DATA LATEST ADDRESS	3	2000
WRITE DATA OLDEST ADDRESS	3	1300
READ INITIATION ADDRESS	3	0
RETRY INITIATION ADDRESS	3	0

FIG. 30

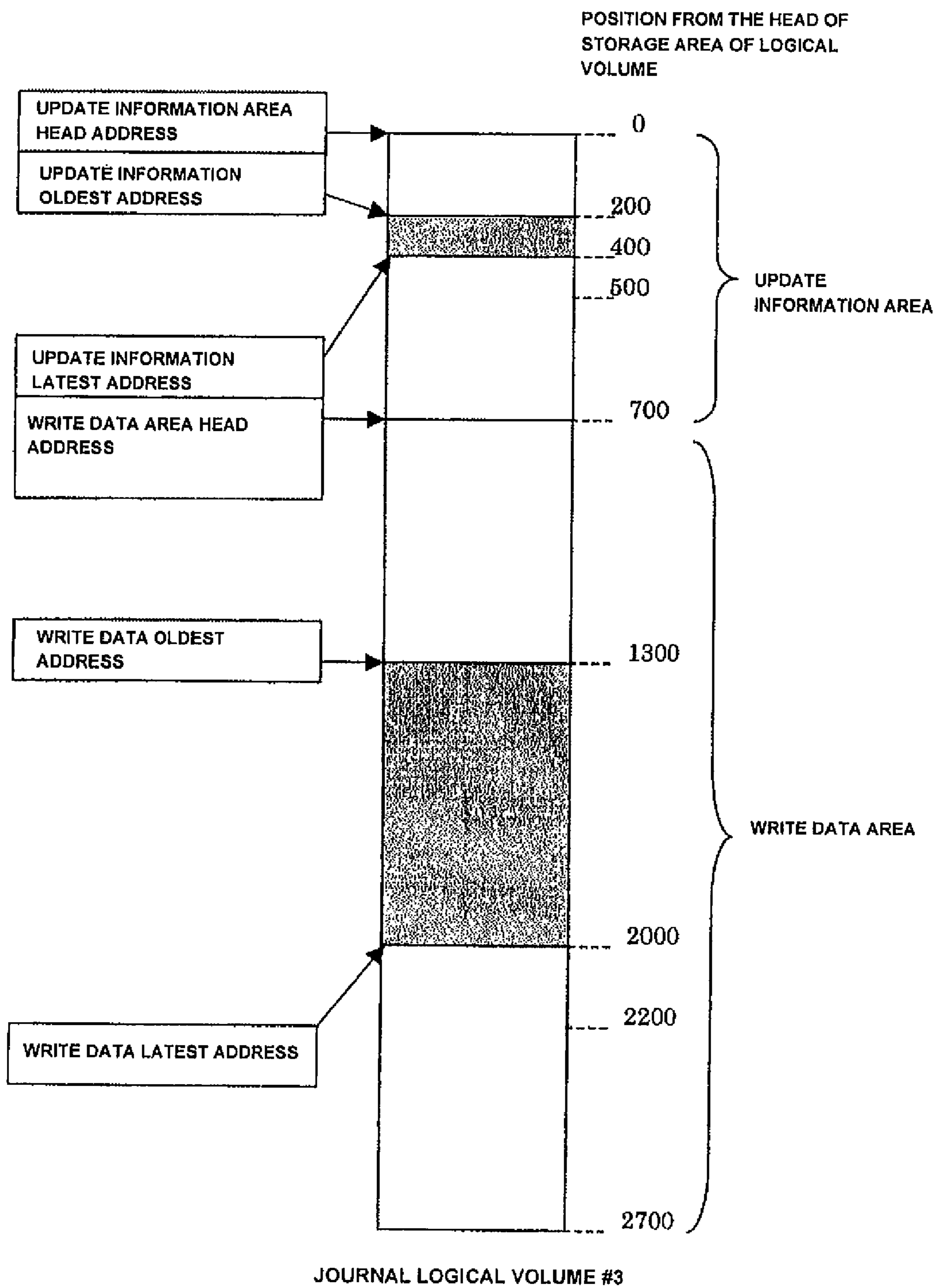


FIG. 31

LOGICAL VOLUME NUMBER	VOLUME STATE	FORMAT	CAPACITY	SYNC PAIR NUMBER	ASYNC PAIR NUMBER	PHYSICAL ADDRESS	
						STORAGE DEVICE NUMBER	POSITION FROM THE HEAD
1	SECONDARY	OPEN3	3	1	0	1	0
2	SECONDARY	OPEN6	6	2	0	1	3
3	NORMAL	OPEN9	9	0	0	2	0

FIG. 32

PAIR NUMBER	PAIR STATE	PRIMARY STORAGE SYSTEM NUMBER	PRIMARY LOGICAL VOLUME NUMBER	SECONDARY STORAGE SYSTEM NUMBER	SECONDARY LOGICAL VOLUME NUMBER	GROUP NUMBER	COPY COMPLETED ADDRESS
1	NORMAL	A	1	C	1	1	0
2	NORMAL	A	2	C	2	1	0
3	DELTA-READY	C	1	B	1	2	0
4	DELTA-READY	C	2	B	2	2	0

FIG. 33

GROUP NUMBER	GROUP STATE	PAIR SET	JOURNAL LOGICAL VOLUME NUMBER	UPDATE NUMBER	REPLICATION TYPE	PARTNER STORAGE SYSTEM NUMBER	PARTNER GROUP NUMBER	DELTA RESERVATION OPTION
1	NORMAL	1,2	3	5	SYNC	A	2	0
2	HALTED	3,4	3	1	ASync	B	2	1

FIG. 34

	LOGICAL ADDRESS	
	LOGICAL VOLUME NUMBER	POSITION FROM THE HEAD OF STORAGE AREA OF LOGICAL VOLUME
UPDATE INFORMATION AREA HEAD ADDRESS	3	0
WRITE DATA AREA HEAD ADDRESS	3	700
UPDATE INFORMATION LATEST ADDRESS	3	500
UPDATE INFORMATION OLDEST ADDRESS	3	0
WRITE DATA LATEST ADDRESS	3	2200
WRITE DATA OLDEST ADDRESS	3	700
READ INITIATION ADDRESS	3	0
RETRY INITIATION ADDRESS	3	0

FIG. 35

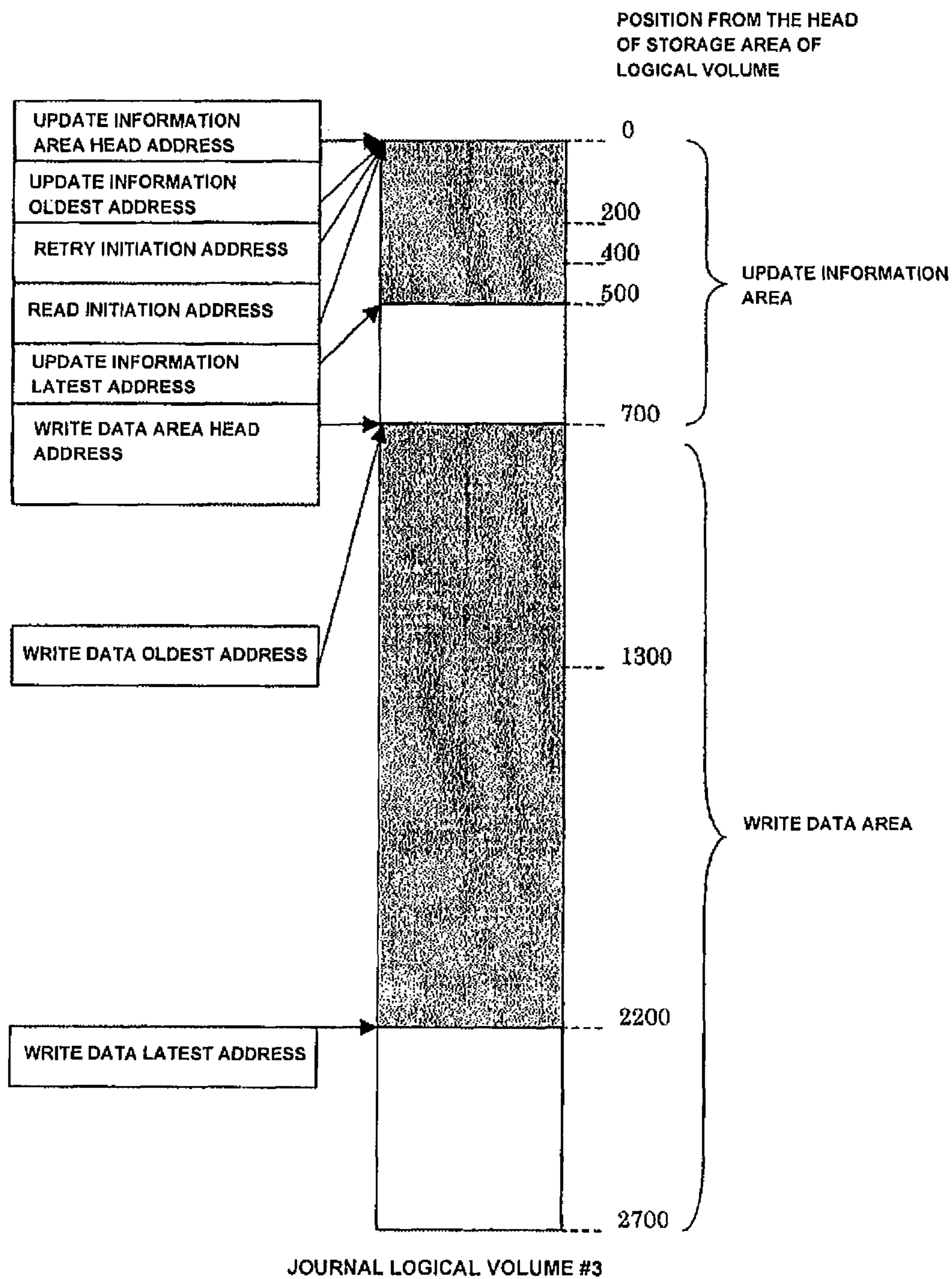


FIG. 36

PAIR NUMBER	PAIR STATE	PRIMARY STORAGE SYSTEM NUMBER	PRIMARY LOGICAL VOLUME NUMBER	SECONDARY STORAGE SYSTEM NUMBER	SECONDARY LOGICAL VOLUME NUMBER	GROUP NUMBER	COPY COMPLETED ADDRESS
1	DELTA-PROCESSING	A	1	B	1	1	0
2	DELTA-PROCESSING	A	2	B	2	1	0
3	NORMAL	C	1	B	1	2	0
4	NORMAL	C	2	B	2	2	0

FIG. 37

GROUP NUMBER	GROUP STATE	PAIR SET	JOURNAL LOGICAL VOLUME NUMBER	UPDATE NUMBER	REPLICATION TYPE	PARTNER STORAGE SYSTEM NUMBER	PARTNER GROUP NUMBER	DELTA RESERVATION OPTION
1	HALTED	1,2	3	4	ASYNC	A	1	0
2	IN PREPARATION	3,4	3	0	ASYNC	C	2	1

FIG. 38

LOGICAL VOLUME NUMBER	VOLUME STATE	FORMAT	CAPACITY	SYNC PAIR NUMBER	ASync PAIR NUMBER	PHYSICAL ADDRESS	
						STORAGE DEVICE NUMBER	POSITION FROM THE HEAD
1	PRIMARY	OPEN3	3	1	3	1	0
2	PRIMARY	OPEN6	6	2	4	1	3
3	NORMAL	OPEN9	9	0	0	2	0

FIG. 39

PAIR NUMBER	PAIR STATE	PRIMARY STORAGE SYSTEM NUMBER	PRIMARY LOGICAL VOLUME NUMBER	SECONDARY STORAGE SYSTEM NUMBER	SECONDARY LOGICAL VOLUME NUMBER	GROUP NUMBER	COPY COMPLETED ADDRESS
1	ABNORMAL	A	1	C	1	1	0
2	ABNORMAL	A	2	C	2	1	0
3	NORMAL	C	1	B	1	1	0
4	NORMAL	C	2	B	2	1	0

FIG. 40

GROUP NUMBER	GROUP STATE	PAIR SET	JOURNAL LOGICAL VOLUME NUMBER	UPDATE NUMBER	REPLICATION TYPE	PARTNER STORAGE SYSTEM NUMBER	PARTNER GROUP NUMBER	DELTA RESERVATION OPTION
1	ABNORMAL	1,2	3	5	SYNC	A	2	0
2	NORMAL	3,4	3	5	ASync	B	2	0

FIG. 41

	LOGICAL ADDRESS	
	LOGICAL VOLUME NUMBER	POSITION FROM THE HEAD OF STORAGE AREA OF LOGICAL
UPDATE INFORMATION AREA HEAD ADDRESS	3	0
WRITE DATA AREA HEAD ADDRESS	3	700
UPDATE INFORMATION LATEST ADDRESS	3	500
UPDATE INFORMATION OLDEST ADDRESS	3	400
WRITE DATA LATEST ADDRESS	3	2200
WRITE DATA OLDEST ADDRESS	3	2000
READ INITIATION ADDRESS	3	400
RETRY INITIATION ADDRESS	3	400

FIG. 42

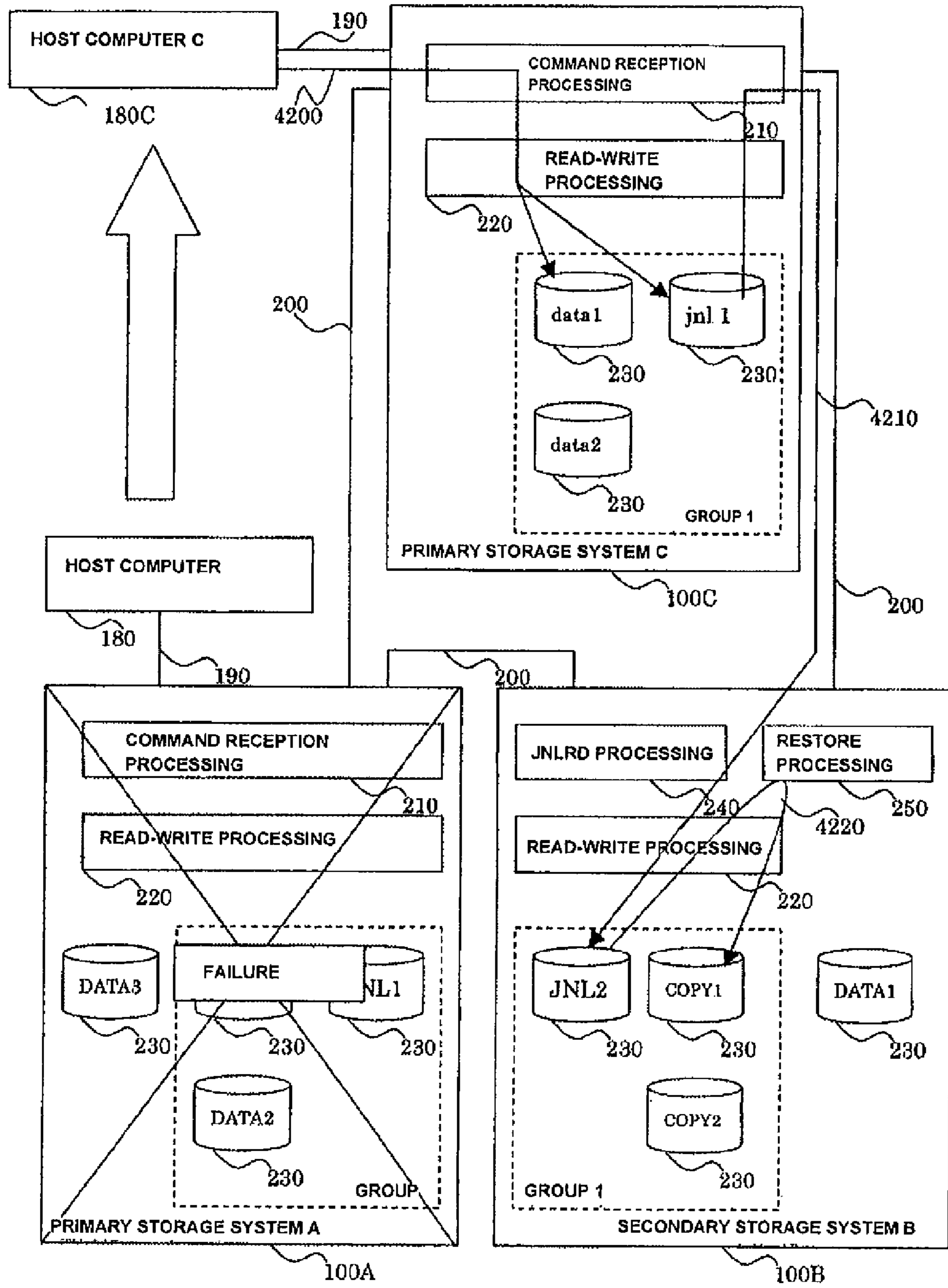


FIG. 43

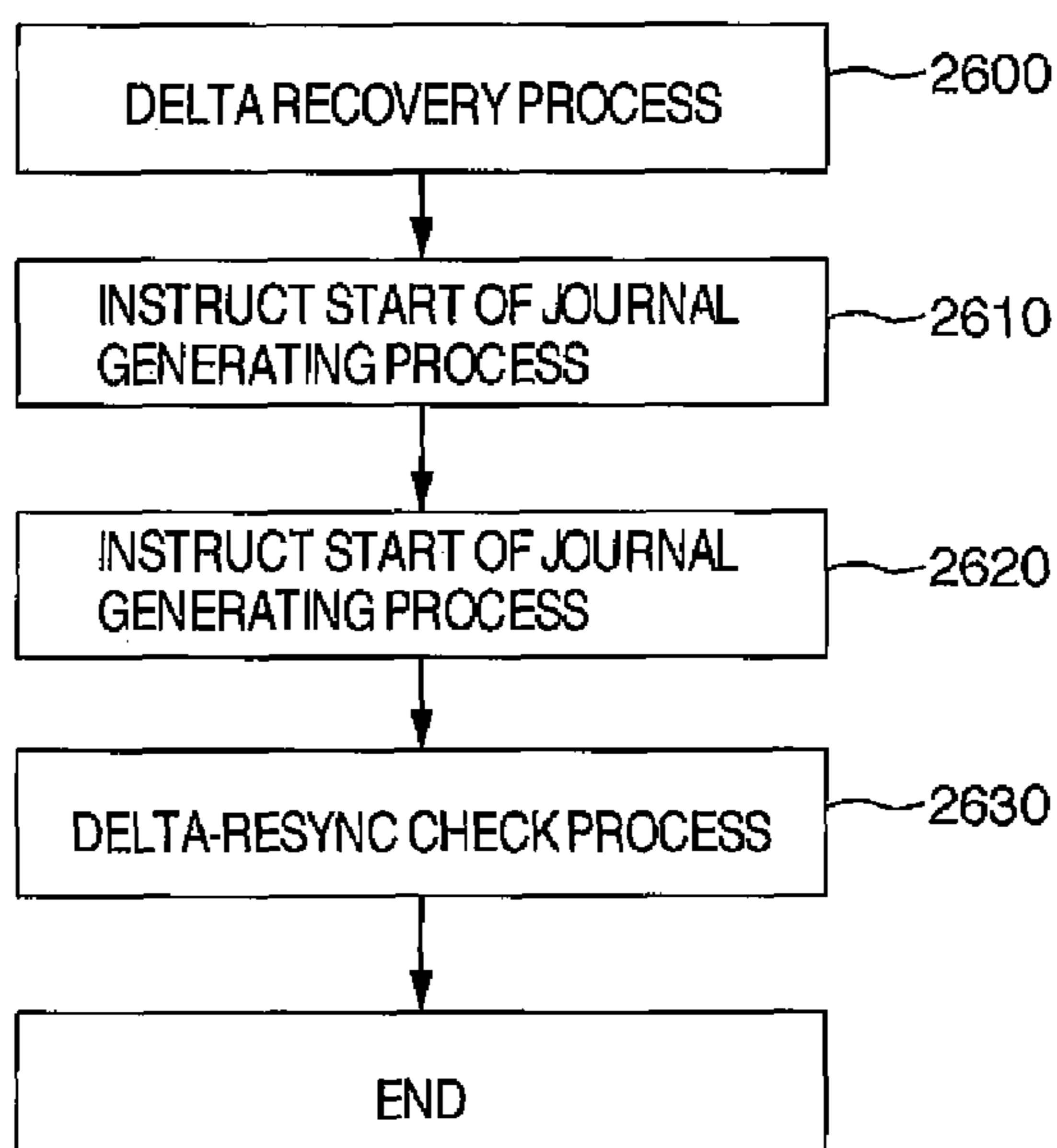


FIG. 44

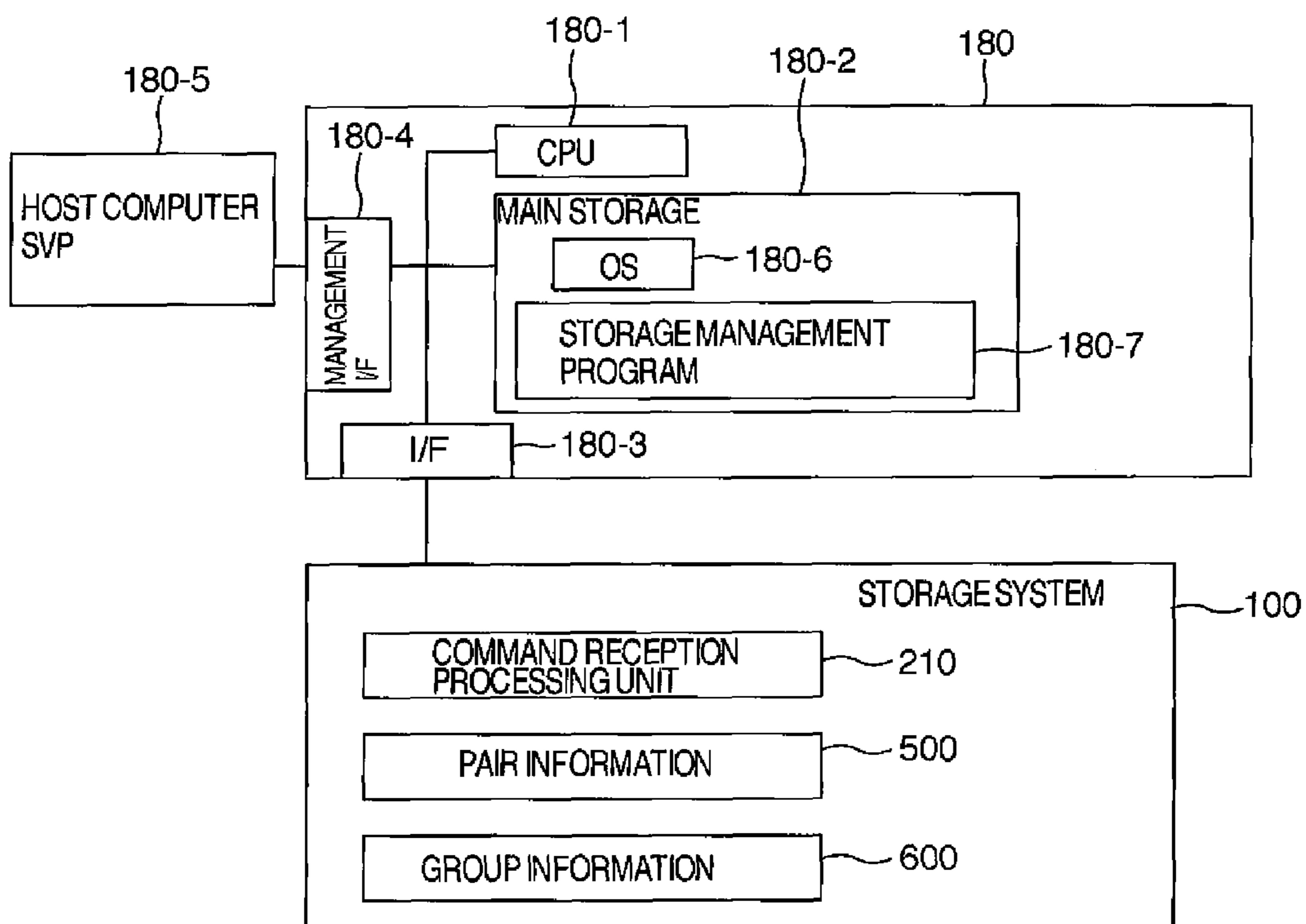
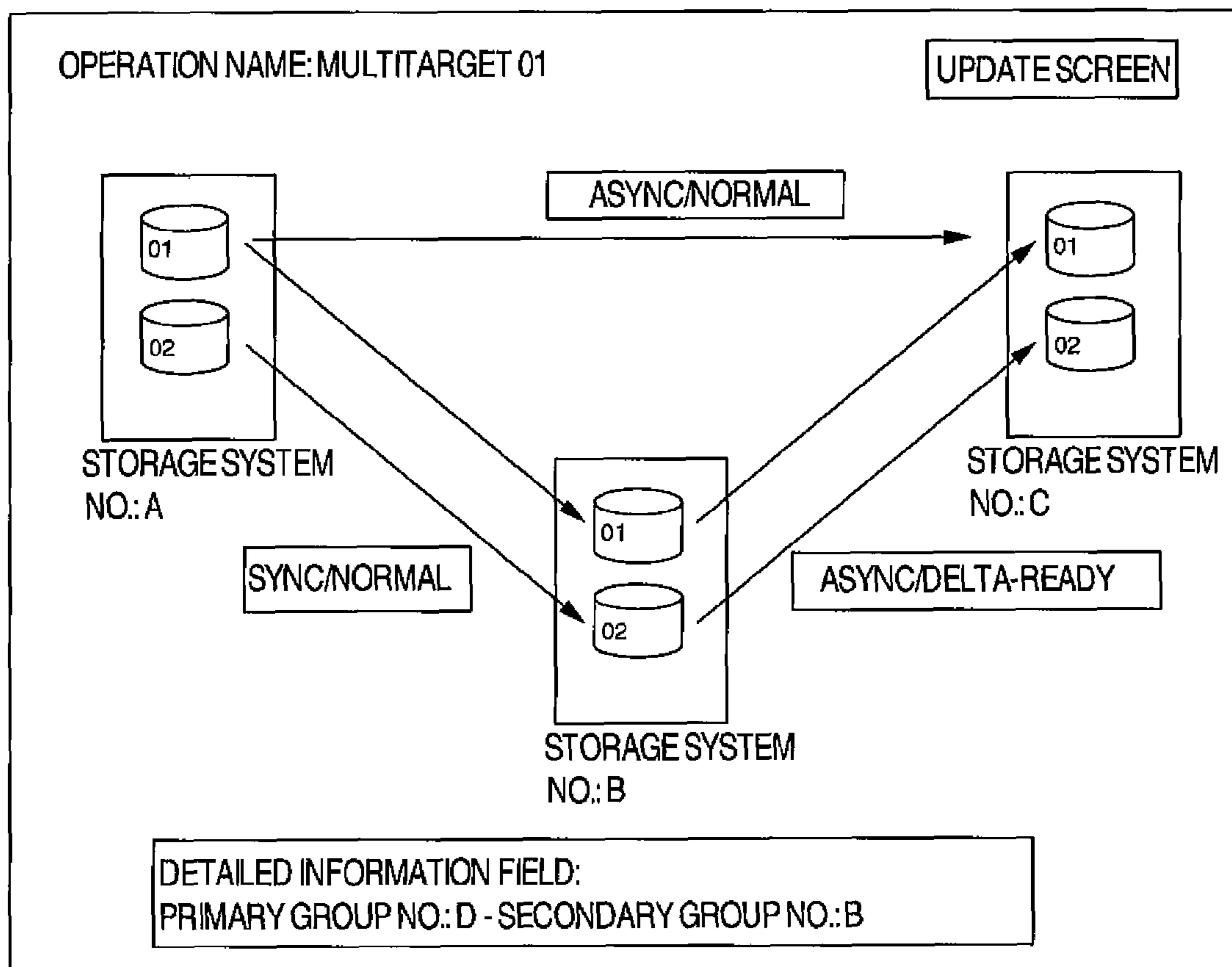
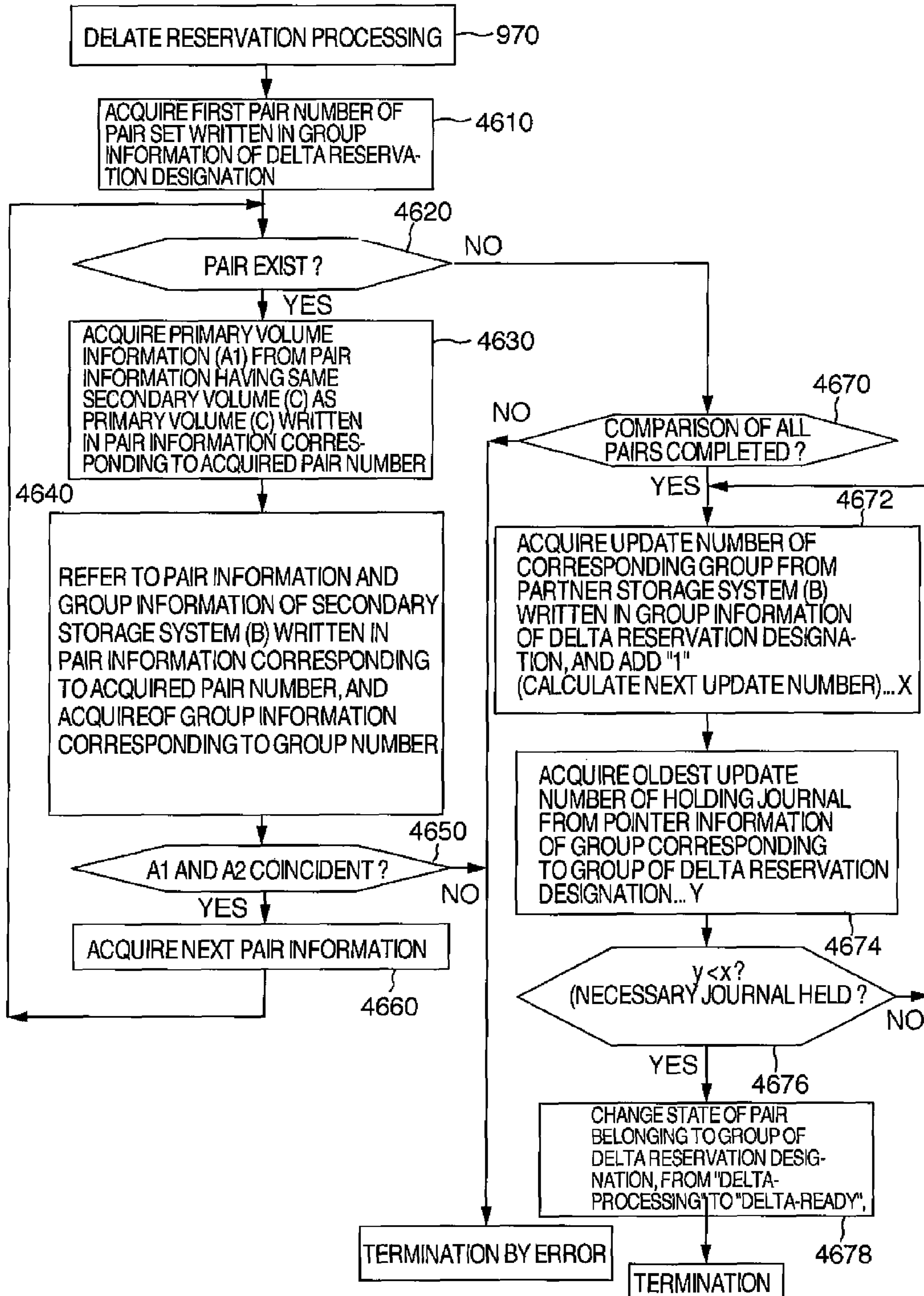


FIG. 45



SCREEN

FIG. 46



COMPUTER SYSTEM AND CONTROL METHOD FOR THE COMPUTER SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

The present application is a continuation application of application Ser. No. 12/877,217, filed Sep. 8, 2010, now U.S. Pat. No. 7,958,306; which is a continuation of Ser. No. 12/366,685, filed Feb. 6, 2009, now U.S. Pat. No. 7,809,887; which is a continuation of application Ser. No. 11/486,160, filed Jul. 14, 2006, now U.S. Pat. No. 7,512,757; which claims priority from Japanese application JP2006-121541 filed on Apr. 26, 2006, the content of which is hereby incorporated by reference into this application.

BACKGROUND OF THE INVENTION

The present invention relates to configuration management or control processing for a computer system, and more particularly to configuration management or control processing for a computer system utilizing remote copy and having a plurality of storage systems.

DESCRIPTION OF THE RELATED ART

Data storage markets have a need for a so-called disaster recovery system which prevents a data loss even if a storage system storing a huge amount of data is destructed by disaster or the like. In order to satisfy this market need, a computer system has been provided which backs up data by utilizing remote copy technology. With this technology, the same data is stored in storage systems installed at two locations sufficiently remote from each other. As data in one storage system is updated, this update is reflected upon the other storage system by remote copy. Integrity of data in two storage systems can therefore be ensured.

JP-A-2003-122509 discloses a computer system which installs storage systems at three locations sufficiently remote from one another, in order to improve security of data. Data integrity between a first storage system used by ordinary business and a remote second storage system is retained by synchronous remote copy. Data integrity between the first storage system and a remote third storage system is retained by asynchronous remote copy.

When the first storage system becomes unable to use for business because of failure to be caused by disaster or the like, the second storage system inherits the business of the first storage system. In this case, if the second storage system cannot be used either, the third storage system inherits the business of the first storage system.

According to JP-A-2003-122509, before the second storage system inherited the business of the first storage system starts operating, data integrity between the second and third storage systems is retained. After the second storage system starts operating, update of data in the second storage system is reflected upon the third storage system by remote copy. Therefore, when a failure occurs in the second storage system, the third storage system can inherit the business of the second storage system.

A data update method of JP-A-2005-84953 discloses means for shortening the time taken to retain data integrity between the second and third storage systems. According to this technique, when data integrity between the second and third storage systems is to be retained, difference data in one storage system is reflected upon the other storage system, to thereby reduce a copy capacity of data and thus realize a time

reduction. In this specification, data integrity retention technique disclosed in JP-A-2005-84953 is called "delta-resync".

As disclosed in JP-A-2005-84953, however, various processings different from conventional remote copy are required in order to perform delta-resync, such as check processings including acquisition of a journal logical volume, storage of change information in the journal logical volume, comparison of change information during delta-resync.

Furthermore, if it is judged that delta-resync is impossible, during check processings after the first storage system is destructed by disaster or the like, all data is copied, posing again the issue solved by JP-A-2005-84953. Namely, long time data copy causes the second storage system impossible to be used for business.

SUMMARY OF THE INVENTION

In order to solve at least one of the problems described above, an embodiment of the present invention provides a computer system having a first storage system connected to a first host computer for establishing communications therewith, a second storage system connected to a second host computer and the first storage system for establishing communications therewith, and a third storage system connected to the first and second storage systems for establishing communications therewith, wherein data written from the first host computer into the first storage system is transferred to the second and third storage systems. The second storage system sets transfer setting before an occurrence of a failure, the transfer setting being provided with a storage area to be used for transferring data to the third storage system.

According to another embodiment, before the start of data transfer between the second storage system and third storage system to be executed after an occurrence of the failure, the second storage system checks the dedicated storage area, data transfer line and transfer setting information, and a check result is reported to the host computer as information attached to the transfer setting.

According to the embodiments of the present invention, the host computer can monitor in advance data transfer setting by the second and third storage systems, so that an unable state of delta-resync can be eliminated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a logical configuration according to one embodiment of the present invention.

FIG. 2 is a block diagram of a storage system in accordance with one embodiment of the present invention.

FIG. 3 is a diagram illustrating the relationship between update information and write data according to one embodiment of the present invention.

FIG. 4 is a diagram illustrating an example of volume information according to one embodiment of the present invention.

FIG. 5 is a diagram illustrating an example of pair information according to one embodiment of the present invention.

FIG. 6 is a block diagram illustrating an example of group information according to one embodiment of the present invention.

FIG. 7 is a block diagram illustrating an example of pointer information according to one embodiment of the present invention.

FIG. 8 is a diagram illustrating the structure of a journal logical volume according to one embodiment of the present invention.

FIG. 9 is a flowchart illustrating the procedure for initiating data replication according to one embodiment of the present invention.

FIG. 10 is a flowchart illustrating an initial copy processing according to one embodiment of the present invention.

FIG. 11 is a diagram illustrating a command reception processing according to one embodiment of the present invention.

FIG. 12 is a flowchart illustrating the command reception processing according to one embodiment of the present invention.

FIG. 13 is a flowchart illustrating a journal creation processing according to one embodiment of the present invention.

FIG. 14 is a diagram illustrating a journal read reception processing according to one embodiment of the present invention.

FIG. 15 is a flowchart illustrating the journal read reception processing according to one embodiment of the present invention.

FIG. 16 is a diagram illustrating a journal read processing according to one embodiment of the present invention.

FIG. 17 is a flowchart illustrating the journal read processing according to one embodiment of the present invention.

FIG. 18 is a flowchart illustrating a journal store processing according to one embodiment of the present invention.

FIG. 19 is a diagram illustrating a restore processing according to one embodiment of the present invention.

FIG. 20 is a flowchart illustrating the restore processing according to one embodiment of the present invention.

FIG. 21 is a diagram illustrating an example of update information according to one embodiment of the present invention.

FIG. 22 is a diagram illustrating an example of update information when a journal creation processing is performed according to one embodiment of the present invention.

FIG. 23 is a flowchart illustrating a remote write command reception processing according to one embodiment of the present invention.

FIG. 24 is a flowchart illustrating a journal replication processing according to one embodiment of the present invention.

FIG. 25 is a flowchart illustrating the procedure for resuming data replication among storage systems in the event a primary storage system 100A fails according to one embodiment of the present invention.

FIG. 26 is a diagram illustrating an example of volume information according to one embodiment of the present invention.

FIG. 27 is a diagram illustrating an example of pair information according to one embodiment of the present invention.

FIG. 28 is a diagram illustrating an example of group information according to one embodiment of the present invention.

FIG. 29 is a diagram illustrating an example of pointer information according to one embodiment of the present invention.

FIG. 30 is a diagram illustrating the structure of a journal logical volume according to one embodiment of the present invention.

FIG. 31 is a diagram illustrating an example of volume information according to one embodiment of the present invention.

FIG. 32 is a diagram illustrating an example of pair information according to one embodiment of the present invention.

FIG. 33 is a diagram illustrating an example of group information according to one embodiment of the present invention.

FIG. 34 is a diagram illustrating an example of pointer information according to one embodiment of the present invention.

FIG. 35 is a diagram illustrating the structure of a journal logical volume according to one embodiment of the present invention.

FIG. 36 is a diagram illustrating an example of pair information according to one embodiment of the present invention.

FIG. 37 is a diagram illustrating an example of group information according to one embodiment of the present invention.

FIG. 38 is a diagram illustrating an example of volume information according to one embodiment of the present invention.

FIG. 39 is a diagram illustrating an example of pair information according to one embodiment of the present invention.

FIG. 40 is a diagram illustrating an example of group information according to one embodiment of the present invention.

FIG. 41 is a diagram illustrating an example of pointer information according to one embodiment of the present invention.

FIG. 42 is a block diagram illustrating the operation which is performed in the event the primary storage system 100A fails according to one embodiment of the present invention.

FIG. 43 is a flowchart illustrating a delta recovery processing according to one embodiment of the present invention.

FIG. 44 is a block diagram illustrating the logical configuration of a portion regarding the host computer 180 and delta-resync according to one embodiment of the present invention.

FIG. 45 is a diagram illustrating an example of GUI according to one embodiment of the present invention.

FIG. 46 is a diagram illustrating a processing of judging whether delta-resync is possible according to one embodiment of the present invention.

DESCRIPTION OF THE EMBODIMENTS

Embodiments of the present invention will be described in detail with reference to the accompanying drawings.

FIG. 1 is a block diagram of a logical configuration of one embodiment of the present invention. According to the present embodiment, a host computer 180 and a storage system 100A are connected by a connection path 190, and the storage system 100A is connected to a storage system 100B and a storage system 100C, which have replications of data stored in the storage system 100A, by connection paths 200. Furthermore, the storage system 100B and the storage system 100C are connected by the connection path 200. In the following description, in order to distinguish between the storage system 100 storing data of a subject of replication and the storage system 100 storing replication data, the storage system 100 storing data of a subject of replication is called a primary storage system 100A in some cases and the storage system 100 storing replication data is called a secondary storage system in some cases. Storage areas within each storage system are managed in divided areas, and each divided storage area is called a logical volume.

In the embodiments, it is assumed that the data update method described in JP-A-2005-84953 is implemented in the storage system 100. Namely, the storage system is implemented with a program for realizing "delta-resync" which

uses a pair of a replication subject and replication data, by transferring only a difference between journals of the storage systems B and C when a failure occurs in the storage system 100A or host computer 180.

The capacity and the physical storage position (a physical address) of each logical volume 230 within each storage system 100 can be designated using a maintenance terminal, such as a computer, or the host computer 180 connected to the storage system 100. The physical address of each logical volume 230 is stored in volume information 400, described later. A physical address is, for example, a number (a storage device number) that identifies a storage device 150 (see FIG. 2) within the storage system 100 and a numerical value that uniquely identifies a storage area within the storage device 150, such as a position from the head of a storage area in the storage device 150. In the following description, a physical address shall be a combination of a storage device number and a position from the head of a storage area within a storage device. Although a logical volume is a storage area of one storage device in the following description, one logical volume can be correlated to storage areas of a plurality of storage devices by converting logical addresses and physical addresses.

Data stored in each storage system 100 can be uniquely designated for referencing and updating purposes by using a number (a logical volume number) that identifies a logical volume and a numerical value that uniquely identifies a storage area, such as a position from the head of a storage area of a logical volume; a combination of a logical volume number and a position from the head of a storage area in the logical volume (a position within logical address) shall hereinafter be called a logical address.

In the following description, in order to readily differentiate data that is the subject of replication from replicated data, the logical volume 230 with data that is the subject of replication shall be called a primary logical volume, while the logical volumes 230 with replicated data shall be called secondary logical volumes. A primary logical volume and a corresponding secondary logical volume shall be called a pair. The state and relationship between a primary logical volume and a secondary logical volume are stored in pair information 500, described later.

A management unit called a group is provided in order to maintain the order of data update between logical volumes. For example, let us assume that the host computer 180 updates data 1 in a primary logical volume 1, and subsequently reads data 1 and uses numerical values of the data 1 to perform a processing to update data 2 in a primary logical volume 2. When a data replication processing from the primary logical volume 1 to a secondary logical volume 1, and a data replication processing from the primary logical volume 2 to a secondary logical volume 2, take place independently, the replication processing of data 2 to the secondary logical volume 2 may take place before the replication processing of data 1 to the secondary logical volume 1. If the replication processing of data 1 to the secondary logical volume 1 is halted due to a failure that occurs between the replication processing of data 2 to the secondary logical volume 2 and the replication processing of data 1 to the secondary logical volume 1, the data integrity between the secondary logical volume 1 and the secondary logical volume 2 is lost. In order to maintain data integrity between the secondary logical volume 1 and the secondary logical volume 2 even in such instances, logical volumes whose data update order must be maintained are registered in the same group, so that an update number from group information 600, described later, is allocated to each logical volume within one group, and a replication pro-

cessing to the secondary logical volumes is performed in the order of update numbers. Update times may be used in place of update numbers. For example, in FIG. 1, a logical volume (DATA 1) and a logical volume (DATA 2) form a group 1 in the primary storage system 100A. Furthermore, a logical volume (data 1), which is a replication of the logical volume (DATA 1), and a logical volume (data 2), which is a replication of the logical volume (DATA 2), form a group 1 in the secondary storage system 100C. Similarly, a logical volume (COPY 1), which is a replication of the logical volume (DATA 1), and a logical volume (COPY 2), which is a replication of the logical volume (DATA 2), form a group 1 in the secondary storage system 100B.

When updating data of the primary logical volumes (DATA 1, DATA 2) that are the subject of replication, the primary storage system 100A creates journals, described later, and stores them in a logical volume of the primary storage system 100A in order to update data of the secondary logical volumes (COPY 1, COPY 2). In the description of the present embodiment example, a logical volume that stores journals only (hereinafter called a "journal logical volume") is allocated to each group. In FIG. 1, the journal logical volume for group 1 is a logical volume (JNL 1).

Similarly, when updating data in the secondary logical volumes (data 1, data 2) of the secondary storage system 100C, the secondary storage system 100C creates journals, described later, and stores them in a journal logical volume within the secondary storage system 100C. In FIG. 1, the journal logical volume for group 1 is a logical volume (jnl 1).

A journal logical volume is allocated to each group within the secondary storage system 100B as well. Each journal logical volume is used to store journals that are transferred from the primary storage system 100A to the secondary storage system 100B. When there is a high load on the secondary storage system 100B, instead of updating data of the secondary logical volumes (COPY 1, COPY 2) when the journals are received, the data of the secondary logical volumes (COPY 1, COPY 2) can be updated later when the load on the secondary storage system 100B is low, for example, by storing journals in the journal logical volume. Furthermore, if there is a plurality of connection paths 200, the transfer of journals from the primary storage system 100A to the secondary storage system 100B can be performed in a multiplex manner to make effective use of the transfer capability of the connection paths 200. Numerous journals may accumulate in the secondary storage system 100B due to update order, but this does not pose any problem since journals that cannot be used immediately for data updating of the secondary logical volumes can be stored in the journal logical volume. In FIG. 1, the journal logical volume for group 1 is a logical volume (JNL 2).

Each journal is comprised of write data and update information. The update information is information for managing write data, and comprises of the time at which a write command was received (update time), a group number, an update number in the group information 600 described later, a logical address of the write command, the size of the write data, and the logical address in the journal logical volume where the write data is stored. The update information may have only either the time at which the write command was received or the update number. If the time at which the write command was created is in the write command from the host computer 180, the time at which the write command was created can be used instead of the time at which the write command was received. Using FIGS. 3 and 21, an example of update information of a journal will be described. Update information 310 stores a write command that was received at 22:20:10 on Mar. 17, 1999. The write command is a command to store write

data at position **700** from the head of a storage area of a logical volume number **1**, and the data size is 300. The write data in the journal is stored beginning at position **1500** from the head of a storage area in a logical volume number **4** (the journal logical volume). From this, it can be seen that the logical volume whose logical volume number is 1 belongs to group **1** and that this is the fourth data update since data replication of group **1** began.

As shown in FIG. 3, each journal logical volume is divided into a storage area for storing update information (an update information area) and a storage area for storing write data (a write data area), for example. In the update information area, update information is stored from the head of the update information area in the order of update numbers; when the update information reaches the end of the update information area, the update information is stored from the head of the update information area again. In the write data area, write data are stored from the head of the write data area; when the write data reach the end of the write data area, the write data are stored from the head of the write data area again. The ratio of the update information area to the write data area can be a fixed value or set through a maintenance terminal or the host computer **180**. Such information is stored in pointer information **700**, described later. In the following description, each journal logical volume is divided into areas for update information and write data; however, a method in which journals, i.e., update information and corresponding write data, are consecutively stored from the head of a logical volume can also be used.

Referring to FIG. 1, an operation for reflecting data update made to the primary logical volume (DATA **1**) of the primary storage system **100A** on the secondary logical volume (data **1**) of the secondary storage system **100C** and the secondary logical volume (COPY **1**) of the secondary storage system **100B** will be generally described.

(1) Upon receiving a write command for data in the primary logical volume (DATA **1**) from the host computer **180**, the primary storage system **100A** updates data in the primary logical volume (DATA **1**), stores journals in the journal logical volume (JNL **1**), and issues a command to the secondary storage system **100C** to update the corresponding data in the secondary logical volume (data **1**) in the secondary system **100C** (a remote write command), through a command reception processing **210** and a read/write processing **220** described later (**270** in FIG. 1).

(2) Upon receiving the remote write command from the primary storage system **100A**, the secondary storage system **100C** updates corresponding data in the secondary logical volume (data **1**) and stores the journals in the journal logical volume (jnl **1**) through the command reception processing **210** and the read/write processing **220**, described later (**270** in FIG. 1).

(3) After receiving a response to the remote write command, the primary storage system **100A** reports the end of the write command to the host computer **180**. As a result, data in the primary logical volume (DATA **1**) in the primary storage system **100A** and data in the secondary logical volume (data **1**) in the secondary storage system **100C** match completely. Such data replication is called synchronous data replication.

(4) The secondary storage system **100B** reads the journals from the primary storage system **100A** through a journal read processing **240**, described later, and stores the journals in the journal logical volume (JNL **2**) through the read/write processing **220** (**280** in FIG. 1).

(5) Upon receiving a journal read command from the secondary storage system **100B**, the primary storage system **100A** reads the journals from the journal logical volume (JNL

1) and sends the journals to the secondary storage system **100B** through the command reception processing **210** and the read/write processing **220**, described later (**280** in FIG. 1).

(6) The secondary storage system **100B** uses the pointer information **700** through a restore processing **250** and the read/write processing **220**, described later, to read the journals from the journal logical volume (JNL **2**) in ascending order of update numbers and updates data in the secondary logical volume (COPY **1**) (**290** in FIG. 1). As a result, data in the primary logical volume (DATA **1**) in the primary storage system **100A** and data in the secondary logical volume (COPY **1**) in the secondary storage system **100B** match completely some time after the update of the primary logical volume (DATA **1**). Such data replication is called asynchronous data replication.

The internal configuration of the storage system **100** is shown in FIG. 2. Each storage system **100** is comprised of one or more host adapters **110**, one or more disk adapters **120**, one or more cache memories **130**, one or more shared memories **140**, one or more storage devices **150**, one or more common paths **160**, and one or more connection lines **170**. The host adapters **110**, the disk adapters **120**, the cache memories **130** and the shared memories **140** are mutually connected by the common paths **160**. The common paths **160** may be redundant in case of a failure of one of the common paths **160**. The disk adapters **120** and the storage devices **150** are connected by the connection lines **170**. In addition, although not shown, a maintenance terminal for setting, monitoring and maintaining the storage system **100** is connected to every host adapter **110** and every disk adapter **120** by a dedicated line.

Each host adapter **110** controls data transfer between the host computer **180** and the cache memories **130**. Each host adapter **110** is connected to the host computer **180** or another storage system **100** via a connection line **190** and the connection path **200**, respectively. Each disk adapter **120** controls data transfer between the cache memories **130** and the storage devices **150**. The cache memories **130** are memories for temporarily storing data received from the host computer **180** or data read from the storage devices **150**. The shared memories **140** are memories shared by all host adapters **110** and disk adapters **120** within the same storage system **100**.

The volume information **400** is information for managing logical volumes and includes volume state, format, capacity, synchronous pair number, asynchronous pair number, and physical address. FIG. 4 shows an example of the volume information **400**. The volume information **400** is stored in a memory, such as the shared memories **140**, that can be referred to by the host adapters **110** and the disk adapters **120**. The volume state is one of "normal," "primary," "secondary," "abnormal," and "blank." The logical volume **230** whose volume state is "normal" or "primary" indicates that the logical volume **230** can be accessed normally from the host computer **180**. The logical volume **230** whose volume state is "secondary" can allow access from the host computer **180**. The logical volume **230** whose volume state is "primary" indicates that it is the logical volume **230** from which data is being replicated. The logical volume **230** whose volume state is "secondary" indicates that it is the logical volume **230** on which replication is made. The logical volume **230** whose volume state is "abnormal" indicates that it is the logical volume **230** that cannot be accessed normally due to a failure. A failure may be a malfunction of the storage device **150** that has the logical volume **230**, for example. The logical volume **230** whose volume state is "blank" indicates that it is not in use. Synchronous pair numbers and asynchronous pair numbers are valid if the corresponding volume state is "primary" or "secondary," and each stores a pair number for specifying

the pair information **500**, described later. If there is no pair number to be stored, an invalid value (for example, "0") is set. In the example shown in FIG. 4, a logical volume **1** has OPEN **3** as format, a capacity of 3 GB, its data stored from the head of a storage area of the storage device **150** whose storage device number is 1, is accessible, and is a subject of data replication.

The pair information **500** is information for managing pairs and includes a pair state, a primary storage system number, a primary logical volume number, a secondary storage system number, a secondary logical volume number, a group number, and a copy complete address (i.e., copied address). FIG. 5 shows an example of the pair information **500**. The pair information **500** is stored in a memory, such as the shared memories **140**, that can be referred to by the host adapters **110** and the disk adapters **120**.

The pair state holds one of "normal", "abnormal", "blank", "copying", "not copied", "delta-ready", "delta-processing" and "abnormal delta". If the pair state is "normal," it indicates that data of the primary logical volume **230** is replicated normally. If the pair state is "abnormal," it indicates that data in the primary logical volume **230** cannot be replicated due to a failure. A failure can be a disconnection of the connection path **200**, for example. If the pair state is "blank," it indicates that the corresponding pair number information is invalid. If the pair state is "copying," it indicates that an initial copy processing, described later, is in progress. If the pair state is "not copied," it indicates that the initial copy processing, described later, has not yet taken place. If the pair state is "delta-ready", it indicates that delta-resync can be performed. If the pair state is "delta-processing", it indicates a preparatory state before transition to delta-ready. If the pair state is "abnormal delta", it indicates that delta-resync or delta-resync preparation is not operated normally because a failure occurs in a journal logical volume or the like to be used for delta-resync. The primary storage system number is a number that specifies the primary storage system **100A** that has the primary logical volume **230**. The secondary storage system number is a number that specifies the secondary storage system **100B** that has the secondary logical volume **230**. The group number is a group number to which the primary logical volume belongs to, if the storage system is the primary storage system. The group number is a group number to which the secondary logical volume belongs to, if the storage system is a secondary storage system. The copy complete address will be described when the initial copy processing is described later. Pair information **1** in FIG. 5 indicates that the subject of data replication is the primary logical volume **1** in the primary storage system A, that the data replication destination is the secondary logical volume **1** in the secondary storage system B, and that the data replication processing has taken place.

FIG. 6 shows an example of the group information **600**. The group information **600** contains information on a group state, a pair set, a journal logical volume number, an update number, a replication type, a partner storage system number, a partner group number, and a delta reservation option. The group information **600** is stored in a memory, such as the shared memories **140**, that can be referred to by the host adapters **110** and the disk adapters **120**.

The group state is one of "normal," "abnormal," "blank," "halted," and "in preparation." If the group state is "normal," it indicates that at least one pair state in the corresponding pair sets is in the "normal" state. If the group state is "abnormal," it indicates that all pair states in the corresponding pair sets are in the "abnormal" state. If the group state is "blank," it indicates that corresponding group number information is invalid. If the storage system is the primary storage system,

the "halted" group state indicates that journals will not be created temporarily. The state is used when the group state is "normal" and journal creation is to be halted temporarily. If the storage system is a secondary storage system, the "halted" group state indicates that the journal read processing will not be carried out temporarily. The state is used when the group state is "normal" and reading journals from the primary storage system is to be temporarily halted. If the group state is "in preparation," it indicates that a data replication initiation processing, described later, is in progress. If the storage system is the primary storage system, each pair set includes pair numbers of all primary logical volumes that belong to the group indicated by the corresponding group number. If the storage system is a secondary storage system, each pair set includes pair numbers of all secondary logical volumes that belong to the group indicated by the corresponding group number. The journal logical volume number indicates the journal logical volume number that belongs to the group with the corresponding group number. If there is no journal logical volume that belongs to the group with the corresponding group number, an invalid value (for example, "0") is set. The update number has an initial value of 1 and changes whenever a journal is created. The update number is stored in the update information of journals and used by the secondary storage system **100B** to maintain the order of data update.

The replication type is either "synchronous" or "asynchronous." If the replication type is "synchronous," the primary logical volume and the secondary logical volume are updated simultaneously. As a result, data in the primary logical volume and data in the secondary logical volume match completely. If the replication type is "asynchronous," the secondary logical volume is updated after the primary logical volume is updated. As a result, data in the primary logical volume and data in the secondary logical volume sometimes do not match (i.e., data in the secondary logical volume is old data of the primary logical volume), but data in the secondary logical volume completely matches data in the primary logical volume after some time.

If the storage system is the primary storage system, the partner storage system number is the secondary storage system number that has the paired secondary logical volume that belongs to the corresponding group. If the storage system is a secondary storage system, the partner storage system number is the primary storage system number that has the paired primary logical volume that belongs to the corresponding group. If the storage system is the primary storage system, the partner group number is the group number to which the paired secondary logical volume of the corresponding group belongs. If the storage system is a secondary storage system, the partner group number is the group number to which the paired primary logical volume of the corresponding group belongs.

The delta reservation option holds information representative of whether the group is registered as a group for delta-resync. In this embodiment, if the delta reservation option is "0", it indicates that the group is registered as a general group, whereas if the delta reservation option is "1", it indicates that the group is registered as a delta-resync group. For example, it can be seen from pair information **1** and **2** that group information **1** shown in FIG. 6 is constituted of primary logical volumes **1** and **2** and a journal logical volume **4**, and that the group can execute a data replication processing (asynchronous) normally as a general group.

The pointer information **700** is stored for each group and is information for managing the journal logical volume for the corresponding group; it includes an update information area head address, a write data area head address, an update infor-

mation latest address, an update information oldest address, a write data latest address, a write data oldest address, a read initiation address, and a retry initiation address. The update information area head address is the logical address at the head of the storage area for storing update information in the journal logical volume (update information area). The write data area head address is the logical address at the head of the storage area for storing write data in the journal logical volume (write data area). The update information latest address is the head logical address to be used for storing update information when a journal is stored next. The update information oldest address is the head logical address that stores update information of the oldest (i.e., having the lowest update number) journal. The write data latest address is the head logical address to be used for storing write data when a journal is stored next. The write data oldest address is the head logical address that stores write data of the oldest (i.e., the having the lowest update number) journal. The read initiation address and the retry initiation address are used only in the primary storage system **100A** in the journal read reception processing, described later.

In the example of the pointer information **700** shown in FIGS. **7** and **8**, the area for storing journal update information (the update information area) spans from the head of the storage areas to position **699** of the logical volume **4**, while the area for storing journal write data (the write data area) spans from position **700** to position **2699** of the storage areas of the logical volume **4**.

The journal update information is stored from position **200** to position **499** of the storage areas of the logical volume **4**, and the next journal update information will be stored beginning at position **500** of the storage areas of the logical volume **4**. The journal write data is stored from position **1300** to position **2199** of the storage areas of the logical volume **4**, and the next journal write data will be stored beginning at position **2200** of the storage areas of the logical volume **4**.

Although a mode in which one journal logical volume is allocated to each group is described below, a plurality of journal logical volumes may be allocated to each group. For example, two journal logical volumes can be allocated to one group, and the pointer information **700** can be provided for each journal logical volume, so that journals can be stored in the two journal logical volumes alternately. By doing this, writing the journals to the storage device **150** can be distributed, which can improve performance. Furthermore, this can also improve the journal read performance. Another example would be one in which two journal logical volumes are allocated to one group, but only one journal logical volume is normally used. The other journal logical volume is used when the performance of the journal logical volume that is normally used declines or the journal logical volume that is normally used fails and cannot be used. An example of the declining performance of the logical volume that is normally used is a case in which a journal logical volume is comprised of a plurality of storage devices **150**, where data are stored in RAID method, and at least one storage device **150** that comprises the RAID fails.

It is preferable for the volume information **400**, the pair information **500**, the group information **600** and the pointer information **700** to be stored in the shared memories **140**. However, the present embodiment example is not limited to this and the information can be stored together or dispersed among the cache memories **130**, the host adapters **110**, the disk adapters **120**, and/or storage devices **150**.

Next, a procedure for initiating data replication (a data replication initiation processing) from the primary storage system **100A** to the secondary storage system **100B** and the

secondary storage system **100C** will be described using FIGS. **9** and **10**. The procedure can for example be a control program stored on a computer readable storage medium executable by a computer system.

(1) Group creation will be described (step **900**). The host computer **180** refers to the group information **600** of the primary storage system **100A** and acquires a group number A having the group state "blank". Similarly, the host computer **180** acquires a group number B of the secondary storage system **100B** (or secondary storage system **100C**). The host computer **180** instructs the primary storage system **100A** to create a group. A group creation instruction is constituted of an instruction subject group number A, a partner storage system number B, a partner group number B, a replication type and a delta reservation option. The delta reservation option is an option instructing whether the group is registered as the general group or as a delta-resync group. In this embodiment, description will be made assuming that if the delta reservation option is "0" or is omitted, the group is registered as the general group, whereas if it is "1", the group is registered as a delta-resync group. The instruction at this step has the delta reservation option "0".

Upon receiving the group creation instruction, the primary storage system **100A** makes changes to the group information **600**. Specifically, the primary storage system **100A** changes the group state of the group information **600** of the instruction subject group number A to "in preparation", the partner storage system number to the designated partner storage system number B, the partner group number to the instructed partner group number B, the replication type to the instructed replication type, and the delta reservation option to the instructed delta reservation option. The primary storage system **100A** sets the update number of the group information **600** to 1 (initial value). Furthermore, the primary storage system **100A** gives a group creation instruction to the storage system having the partner storage system number B. The instruction subject group number of the group creation instruction is the partner group number B, the partner storage system number is the storage system number of the primary storage system **100A**, the partner group number is the instruction object group number A, the replication type is the instructed replication type, and the delta reservation option is the instructed delta reservation option.

(2) Next, pair registration (step **910**) will now be described. Using the maintenance terminal or the host computer **180**, the user designates information that indicates the subject of data replication and information that indicates the data replication destination and gives a pair registration instruction to the primary storage system **100A**. The information that indicates the subject of data replication is the group number A and the primary logical volume number A that are the subject of data replication. The information that indicates the data replication destination is the secondary logical volume number B in the secondary storage system **100B** for storing the replication data.

Upon receiving the pair registration instruction, the primary storage system **100A** obtains a pair number whose pair state is "blank" from the pair information **500** and sets "not copied" as the pair state; the primary storage system number A that indicates the primary storage system **100A** as the primary storage system number; the primary logical volume number A instructed as the primary logical volume number; the partner storage system number of the group number A in the group information **600** as the secondary storage system number; the secondary logical volume number B instructed as the secondary logical volume number; and the group number A instructed as the group number. The primary storage

system 100A adds the pair number obtained for the group number A instructed to the pair set in the group information 600, and changes the volume state of the primary logical volume number A to "primary."

The primary storage system 100A notifies the partner storage system for the group number A instructed in the group information 600 of the primary storage system number A indicating the primary storage system 100A, the partner group number B for the group number A in the group information 600, the primary logical volume number A, and the secondary logical volume number B, and commands a pair registration. The secondary storage system 100B obtains a blank pair number whose pair state is "blank" from the pair information 500 and sets "not copied" as the pair state; the primary storage system number A notified as the primary storage system number; the primary logical volume number A notified as the primary logical volume number; the secondary storage system number B as the secondary storage system number; the secondary logical volume number B notified as the secondary logical volume number; and the group number B notified as the group number. Additionally, the secondary storage system 100B adds the pair number obtained to the pair set for the group number B instructed in the group information 600, and changes the volume state of the secondary volume number B to "secondary."

The above operation is performed on all pairs that are the subject of data replication.

Although registering logical volumes with a group and setting logical volume pairs are performed simultaneously according to the processing, they can be done individually.

(3) Next, journal logical volume registration (step 920) will be described. Using the maintenance terminal or the host computer 180, the user gives the primary storage system 100 A an instruction to register the logical volume to be used for storing journals (a journal logical volume) with a group (a journal logical volume registration instruction). The journal logical volume registration instruction is comprised of a group number and a logical volume number.

The primary storage system 100A registers the logical volume number instructed as the journal logical volume number for the group number instructed in the group information 600. In addition, the primary storage system 100 A sets the volume state of the logical volume to "normal" in the volume information 400.

Similarly, using the maintenance terminal or the host computer 180, the user refers to the volume information 400 for the secondary storage system 100B, designates the secondary storage system 100B, the group number B, and the logical volume number to be used as the journal logical volume, and gives a journal logical volume registration instruction to the primary storage system 100A. The primary storage system 100A transfers the journal logical volume registration instruction to the secondary storage system 100B. The secondary storage system 100B registers the logical volume number instructed as the journal logical volume number for the group number B instructed in the group information 600. In addition, the secondary storage system 100B sets the volume state for the corresponding logical volume to "normal" in the volume information 400.

Alternatively, using the maintenance terminal of the secondary storage system 100B or the host computer 180 connected to the secondary storage system 100B, the user may designate the group number and the logical volume number to be used as the journal logical volume and give a journal logical volume registration instruction to the secondary storage system 100B. The user would then do the same with the secondary storage system 100C.

The operations described are performed on all logical volumes that are to be used as journal logical volumes. However, step 910 and step 920 may be reversed in order.

(4) Next, data replication processing initiation (step 930) will be described. Using the maintenance terminal or the host computer 180, the user designates a group number C, whose replication type is synchronous, and the group number B, whose replication type is asynchronous, for initiating the data replication processing, and instructs the primary storage system 100A to initiate the data replication processing. The primary storage system 100A sets all copy complete addresses in the pair information 500 that belong to the group B to 0.

The primary storage system 100A instructs the partner storage system 100B for the group number B in the group information 600 to change the group state of the partner group number of the group number B in the group information 600 to "normal" and to initiate the journal read processing and the restore processing, described later. The primary storage system 100A instructs the partner storage system 100 C for the group number C in the group information 600 to change the group state of the partner group number of the group number C to "normal" in the group information 600.

The primary storage system 100A changes the group state of the group number C and of the group number B to "normal" and initiates the initial copy processing, described later.

Although the synchronous data replication processing initiation and the asynchronous data replication processing initiation are instructed simultaneously according to the description, they can be performed individually.

(5) Next, an initial copy processing end (step 940) will be described.

When the initial copying is completed, the primary storage system 100A notifies the end of the initial copy processing to the secondary storage system 100B and the secondary storage system 100C. The secondary storage system 100B and the secondary storage system 100C change the pair state of every secondary logical volume that belongs to either the group B or the group C to "normal."

(6) Group creation for delta-resync will be described (step 950). The host computer 180 instructs to create a group for delta-resync. A group creation instruction is constituted of an instruction subject group number C, a partner storage system number B, a partner group number B, a replication type and a delta reservation option. In this case, the delta reservation option is "1".

Upon receiving the group creation instruction, the secondary storage system 100C changes the group information. Specifically, the secondary storage system 100C changes the group state of the group information 600 of the instruction subject group number C to "halt", the partner storage system number to the instructed storage system number B, the partner group number to the instructed partner group number B, the replication type to the instructed replication type, and the delta reservation option to the instructed delta reservation option. The secondary storage system 100C instructs the storage system of the partner storage system number B to create a group. The instruction subject group number of the group creation instruction is set to the partner group number B, the partner storage system number is set to the storage system number of the secondary storage system 100C, the partner group number is set to the instruction subject group number C, the replication type is set to the instructed replication type, and the delta reservation option is set to the instructed delta reservation option.

(7) Pair registration for delta-resync will be described (step 960). The host computer 180 designates information repre-

representative of a data replication subject and information representative of data replication destination, and instructs the secondary storage system **100C** to register a pair. The information representative of a data replication subject includes the group number **C** of the data replication subject and the primary logical volume number **C**. The information representative of a data replication destination includes the secondary logical volume number **B** of the secondary storage system **100B** storing replication data.

Upon receiving the pair registration instruction, the secondary storage system **100C** acquires a pair number having pair information "blank" from the pair information **500**. Since the delta reservation option of the corresponding group number **C** is "1", "delta-processing" is set to the pair state, the primary storage system number **C** representative of the secondary storage system **100C** is set to the primary storage system number, the instructed primary logical volume number **C** is set to the primary logical volume number, the partner storage system number of the group number **C** of the group information **600** is set to the secondary storage system, the instructed secondary logical volume number **B** is set to the secondary logical volume number, and the instructed group number **C** is set to the group number. The acquired pair number is added to the pair set of the group information **600** of the instructed group number **C**.

The secondary storage system **100C** notifies the partner storage system in the group information **600** of the instructed group number **C**, the primary storage system number **C** indicating the secondary storage system **100C**, the partner group number **B**, primary logical volume number **C** and secondary logical volume number **B** respectively of the group information **600** of the group number **C**, and then instructs to register the pair. The secondary storage system **100B** acquires a pair number having pair information "blank" from the pair information **500**. Since the delta reservation option of the corresponding group number **B** is "1", "delta-processing" is set to the pair state, the notified primary storage system number **C** is set to the primary storage system number, the notified primary logical volume number **C** is set to the primary logical volume number, the notified primary logical volume number **C** is set to the primary logical volume number, the notified secondary storage system number **B** is set to the secondary storage system number, the notified secondary volume number **B** is set to the secondary logical volume number, and the notified group number **B** is set to the group number. The secondary storage system **100B** adds the acquired pair number to the pair set of the group information of the instructed group number **B**.

The above operations are performed for all pairs which are the subjects of delta-resync.

(8) A delta reservation processing will be described (step **970**). The host computer **180** designates a group number **C** whose replication type is asynchronous and delta reservation option is "1", for starting the delta reservation processing, and instructs the secondary storage system **100C** to start the delta reservation processing. Delta-resync is a processing by which only differences between the primary logical volume **A** of the primary storage system **100A** and paired secondary logical volumes **B** and **C** of the secondary storage systems **100B** and **100C** are copied to establish data synchronization.

Upon receiving the instruction, the secondary storage system **100C** checks whether delta-resync is possible. Namely, it is judged whether replication subjects of two groups having the pair registered for delta-resync are coincident and the pair numbers are coincident. If it is judged that delta-resync is possible, the pair state of the pair information **500** of the

corresponding group number is changed to "delta-ready". These operations are the delta reservation processing.

Next, a judgment processing at step **970** will be described in detail with reference to FIG. **46**.

First, the storage system **100C** acquires a first pair number of the pair set described in the group information of delta reservation designation (step **4610**).

The storage system **100C** extracts pair information having the secondary storage system number and secondary logical volume number having the same numbers as the primary storage system number **C** and primary logical volume number **C** of the pair having the designated group number **C**, from the pair information **500**, and acquires a primary storage system number **A1** and a primary logical volume number **A1** from the extracted pair information (step **4630**). Next, the storage system **100C** acquires a primary storage system number **A2** and a primary logical volume number **A2** of a pair which has, as their replication destination, the secondary storage system number **B** and secondary logical volume number **D** corresponding to the primary storage system number **C** and primary logical volume number **C** and has a group number whose delta reservation option is not "1", from the secondary storage system **100B** having the secondary logical volume number **B** corresponding to the primary storage system number **C** and primary logical volume number **C** (step **4640**). The storage system **100C** judges whether the acquired primary storage system number **A1** and primary logical volume number **A1** are coincident with the acquired primary storage system number **A2** and primary logical volume number **A2** (step **4650**). This judgment is performed for all pairs having the designated group number **C** at a loop from step **4620** to step **4660**.

If this judgment (step **4650**) indicates incoincidence, the delta reservation processing is terminated as an error.

It is judged whether comparison of the designated pair is completed (step **4670**), and if completed, it is judged through comparison whether the journal data is transferred which is necessary for delta-resync.

First, the storage system **100C** acquires, from the secondary storage system **100B** having the partner storage system number **B** written in the group number having the designated group number **C** and the delta reservation option of "1", in the group information **600**, a numerical value **B1** obtained by adding "1" to an update number **B** of the group having a pair which has the same secondary logical volume as the secondary logical volume of the pair belonging to the group having the partner group number **B** written in the group number (step **4672**). Next, the storage system **100C** refers to the pointer information **700** to check whether it has the journal of the update number **B**. The storage system **100C** reads update information of an update information oldest address of the pointer information from the storage device **150** to obtain the oldest (smallest) update number **C** (step **4674**). The storage system **C** compares the value acquired at step **4672** with the value acquired at step **4674** (step **4676**), and if the update number **C** is equal to or smaller than the acquired update number **B1**, it means that the storage system has the journal of the update number **B**, so that it is judged that delta-resync is possible (step **4678**).

FIG. **10** is a flowchart of the initial copy processing. In the initial copy processing, using copy complete addresses in the pair information **500**, a journal is created per unit size in sequence from the head of storage areas for all storage areas of the primary logical volume that is the subject of data replication. Copy complete addresses have an initial value of 0, and the amount of data created is added each time a journal is created. The storage areas from the head of the storage areas

of each logical volume to one position prior to the copy complete addresses represent storage areas for which journals have been created through the initial copy processing. By performing the initial copy processing, data in the primary logical volume that have not been updated can be transferred to the secondary logical volume. A host adapter A within the primary storage system **100A** performs the processing according to the following description, but the processing may be performed by the disk adapters **120**.

(1) The host adapter A within the primary storage system **100A** obtains a primary logical volume A that is part of a pair that belongs to the asynchronous replication type group B, which is the subject of processing, and whose pair state is “not copied”; the host adapter A changes the pair state to “copying” and repeats the following processing (steps **1010**, **1020**). If there is no primary logical volume A, the host adapter A terminates the processing (step **1030**).

(2) If the primary logical volume A is found in step **1020** to exist, the host adapter A creates a journal per data unit size (for example, 1 MB data). The journal creation processing is described later (step **1040**).

(3) To update data in the secondary logical volume that forms a synchronous pair with the primary logical volume A, the host adapter A sends a remote write command to the secondary storage system C, which has the secondary logical volume that is part of the synchronous pair. The remote write command includes a write command, a logical address (where the logical volume is the secondary logical volume C of the synchronous pair number, and the position within the logical volume is the copy complete address), data amount (unit size), and the update number used in step **1040**. Instead of the update number, the time at which the journal was created may be used (step **1045**). The operation of the secondary storage system C when it receives the remote write command will be described in a command reception processing **210**, described later.

(4) Upon receiving a response to the remote write command, the host adapter A adds to the copy complete address the data size of the journal created (step **1050**).

(5) The above processing is repeated until the copy complete addresses reach the capacity of the primary logical volume A (step **1060**). When the copy complete addresses become equal to the capacity of the primary logical volume A, which indicates that journals have been created for all storage areas of the primary logical volume A, the host adapter A updates the pair state to “normal” and initiates the processing of another primary logical volume (step **1070**).

Although logical volumes are described as the subject of copying one at a time according to the flowchart, a plurality of logical volumes can be processed simultaneously.

FIG. **11** is a diagram illustrating the processing of the command reception processing **210**; FIG. **12** is a flowchart of the command reception processing **210**; FIG. **13** is a flowchart of a journal creation processing; FIG. **23** is a flowchart of a remote write command reception processing; and FIG. **24** is a flowchart of a journal replication processing. Next, by referring to these drawings, a description will be made as to an operation that takes place when the primary storage system **100A** receives a write command from the host computer **180** to write to the logical volume **230** that is the subject of data replication.

(1) The host adapter A within the primary storage system **100A** receives an access command from the host computer **180**. The access command includes a command such as a read, write or journal read command, described later, as well as a logical address that is the subject of the command, and data amount. Hereinafter, the logical address shall be called a

logical address A, the logical volume number a logical volume A, the position within the logical volume a position A within the logical volume, and the data amount a data amount A, in the access command (step **1200**).

(2) The host adapter A checks the access command (steps **1210**, **1215**, **1228**). If the access command is found through checking in step **1215** to be a journal read command, the host adapter A performs the journal read reception processing described later (step **1220**). If the access command is found to be a remote copy control command, the host adapter A performs a remote copy control command reception processing described later (step **2300**).

(3) If the access command is found through checking in step **1210** to be a write command, the host adapter A refers to the logical volume A in the volume information **400** and checks the volume state (step **1240**). If the volume state of the logical volume A is found through checking in step **1240** to be other than “normal” or “primary,” which indicates that the logical volume A cannot be accessed, the host adapter A reports to the host computer **180** that the processing ended abnormally (step **1245**).

(4) If the volume state of the logical volume A is found through checking in step **1240** to be either “normal” or “primary,” the host adapter A reserves at least one cache memory **130** and notifies the host computer **180** that the primary storage system **100A** is ready to receive data. Upon receiving the notice, the host computer **180** sends write data to the primary storage system **100A**. The host adapter A receives the write data and stores it in the cache memory **130** (step **1250** **1100** in FIG. **11**).

(5) The host adapter A refers to the volume information, pair information and group information of the logical volume A and checks whether the logical volume A is the subject of asynchronous replication (step **1260**). If through checking in step **1260** the volume state of the logical volume A is found to be “primary,” the pair state of the pair with the asynchronous pair number that the logical volume A belongs to is “normal,” and the group state of the group that the pair belongs to is “normal,” these indicate that the logical volume A is the subject of asynchronous replication; consequently, the host adapter A performs the journal creation processing described later (step **1265**).

(6) The host adapter A refers to the volume information, pair information and group information of the logical volume A and checks whether the logical volume A is the subject of synchronous replication (step **1267**). If through checking in step **1267** the volume state of the logical volume A is found to be “primary,” the pair state of the pair with the synchronous pair number that the logical volume A belongs to is “normal,” and the group state of the group that the pair belongs to is “normal,” these indicate that the logical volume A is the subject of synchronous replication; consequently, the host adapter A sends to the secondary storage system C having the logical volume that forms the pair with the synchronous pair number a remote write command to store the write data received from the host computer **180** (**1185** in FIG. **11**). The remote write command includes a write command, a logical address (where the logical volume is the secondary logical volume C that forms the pair with the synchronous pair number, and the position within the logical volume is the position A within the logical volume), data amount A, and the update number used in step **1265**. Instead of the update number, the time at which the write command was received from the host computer **180** may be used. If the logical volume is found through checking in step **1267** not to be the logical volume that is the subject of synchronous replication, or if the journal

creation processing in step **1265** is not successful, the host adapter A sets the numerical value “0,” which indicates invalidity, as the update number.

(7) Upon receiving a response to step **1267** or to the remote write command in step **1268**, the host adapter A commands the disk adapter **120** to write the write data to the storage area of the storage device **150** that corresponds to the logical address A (**1160** in FIG. **11**), and reports to the host computer **180** that the processing ended (steps **1270**, **1280**). Subsequently, the disk adapter **120** stores the write data in the storage area through the read/write processing (**1170** in FIG. **11**).

Next, the journal creation processing will be described.

(1) The host adapter A checks the volume state of the journal logical volume (step **1310**). If the volume state of the journal logical volume is found through checking in step **1310** to be “abnormal,” journals cannot be stored in the journal logical volume; consequently, the host adapter A changes the group state to “abnormal” and terminates the processing (step **1315**). In such a case, the host adapter A converts the journal logical volume to a normal logical volume.

(2) If the journal logical volume is found through checking in step **1310** to be in the “normal” state, the host adapter A continues the journal creation processing. The journal creation processing entails different processing depending on whether the processing is part of an initial copy processing or a part of a command reception processing (step **1320**). If the journal creation processing is a part of a command reception processing, the host adapter A performs the processing that begins with step **1330**. If the journal creation processing is a part of an initial copy processing, the host adapter A performs the processing that begins with step **1370**.

(3) If the journal creation processing is a part of a command reception processing, the host adapter A checks whether the logical address A that is the subject of writing is set as the subject of initial copy processing (step **1330**). If the pair state of the logical volume A is “not copied,” the host adapter A terminates the processing without creating any journals, since a journal creation processing will be performed later as part of an initial copy processing (step **1335**). If the pair state of the logical volume A is “copying,” and if the copy complete address is equal to or less than the position A within the logical address, the host adapter A terminates the processing without creating any journals, since a journal creation processing will be performed later as part of an initial copy processing (step **1335**). Otherwise, i.e., if the pair state of the logical volume A is “copying” and if the copy complete address is greater than the position A within the logical address, or if the pair state of the logical volume A is “normal,” the initial copy processing is already completed, and the host adapter A continues the journal creation processing.

(4) Next, the host adapter A checks whether a journal can be stored in the journal logical volume. The host adapter A uses the pointer information **700** to check whether there are any blank areas in the update information area (step **1340**). If the update information latest address and the update information oldest address in the pointer information **700** are equal, which indicates that there are no blank areas in the update information area, the host adapter A terminates the processing due to a failure to create a journal (step **1390**).

If a blank area is found in the update information area through checking in step **1340**, the host adapter A uses the pointer information **700** to check whether the write data can be stored in the write data area (step **1345**). If the write data oldest address falls within a range of the write data latest address and a numerical value resulting from adding the data

amount A to the write data latest address, which indicates that the write data cannot be stored in the write data area, the host adapter A terminates the processing due to a failure to create a journal (step **1390**).

(5) If the journal can be stored, the host adapter A obtains a logical address for storing the update number and update information, as well as a logical address for storing write data, and creates update information in at least one cache memory **130**. The update number set in the group information **600** is a numerical value resulting from adding 1 to the update number of the subject group obtained from the group information **600**. The logical address for storing the update information is the update information latest address in the pointer information **700**, and a numerical value resulting from adding the size of the update information to the update information latest address is set as the new update information latest address in the pointer information **700**. The logical address for storing the write data is the write data latest address in the pointer information **700**, and a numerical value resulting from adding the data amount A to the write data latest address is set as the new write data latest address in the pointer information **700**.

The host adapter A sets as the update information the numerical values obtained, the group number, the time at which the write command was received, the logical address A within the write command, and the data amount A (step **1350** **1120** in FIG. **11**). For example, if a write command to write a data size of 100 beginning at position **800** from the head of the storage area of the primary logical volume **1** that belongs to group **1** in the state of the group information **600** shown in FIG. **6** and the pointer information **700** shown in FIG. **7** is received, the update information shown in FIG. **22** is created. The update number for the group information is 6, the update information latest address in the pointer information is 600 (the update information size is 100), and the write data latest address is 2300.

(6) The host adapter A commands the disk adapter **120** to write the update information and write data of the journal on the storage device **150** and ends the processing normally (step **1360** **1130**, **1140** and **1150** in FIG. **11**).

(7) If the journal creation processing is a part of an initial copy processing, the host adapter A performs the processing that begins with step **1370**. The host adapter A checks whether a journal can be created. The host adapter A uses the pointer information **700** to check whether there are any blank areas in the update information area (step **1370**). If the update information latest address and the update information oldest address in the pointer information **700** are equal, which indicates that there are no blank areas in the update information area, the host adapter A terminates the processing due to a failure to create a journal (step **1390**). Since the write data of journals is read from the primary logical volume and no write data areas are used in the initial copy processing described in the present embodiment example, there is no need to check whether there are any blank areas in the write data area.

(8) If it is found through checking in step **1370** that a journal can be created, the host adapter A creates update information in at least one cache memory **130**. The time the update number was obtained is set as the time the write command for the update information was received. The group number that a pair with an asynchronous pair number of the logical volume belongs to is set as the group number. The update number set in the group information **600** is a numerical value resulting from adding 1 to the update number obtained from the group information **600**. The logical address that is the subject of the initial copy processing (copy complete address in the pair information) is set as the logical address of the write command and the logical address of the journal

logical volume storing the write data. The unit size of the initial copy processing is set as the data size of the write data. The logical address for storing update information is the position of the update information latest address in the pointer information **700**, and a numerical value resulting from adding the size of the update information to the update information latest address is set as the new update information latest address in the pointer information **700** (step **1380 1120** in FIG. **11**).

(9) The host adapter A commands the disk adapter **120** to write the update information to the storage device **150** and ends the processing normally (step **1385 1140** and **1150** in FIG. **11**).

Although the update information is described to be in at least one cache memory **130** according to the description above, the update information may be stored in at least one shared memory **140**.

Write data does not have to be written to the storage device **150** asynchronously, i.e., immediately after step **1360** or step **1385**. However, if the host computer **180** issues another command to write in the logical address A, the write data in the journal will be overwritten; for this reason, the write data in the journal must be written to the storage device **150** that corresponds to the logical address of the journal logical volume in the update information before the subsequent write data is received from the host computer **180**. Alternatively, the write data can be saved in a different cache memory and later written to the storage device **150** that corresponds to the logical address of the journal logical volume in the update information.

Although journals are stored in the storage devices **150** according to the journal creation processing described, the cache memory **130** having a predetermined amount of memory for journals can be prepared in advance and the cache memory **130** can be used fully before the journals are stored in the storage device **150**. The amount of cache memory for journals can be designated through the maintenance terminal, for example.

Next, a description will be made as to a processing that takes place when a host adapter C of the secondary storage system **100C** receives a remote write command from the primary storage system **100A** (a remote write command reception processing). A remote write command includes a write command, a logical address (a secondary logical volume C, a position A within the logical volume), a data amount A, and an update number.

(1) The host adapter C in the secondary system **100C** refers to the volume information **400** for the logical volume C and checks the volume state of the secondary logical volume C (step **2310**). If the volume state of the logical volume C is found through checking in step **2310** to be other than "secondary," which indicates that the logical volume C cannot be accessed, the host adapter C reports to the primary storage system **100A** that the processing ended abnormally (step **2315**).

(2) If the volume state of the logical volume C is found through checking in step **2310** to be "secondary," the host adapter C reserves at least one cache memory **130** and notifies the primary storage system **100A** of its readiness to receive data. Upon receiving the notice, the primary storage system **100A** sends write data to the secondary storage system **100C**. The host adapter C receives the write data and stores it in the cache memory **130** (step **2320**).

(3) The host adapter C checks the update number included in the remote write command and if the update number is the invalid value "0," which indicates that journals were not cre-

ated in the primary storage system **100A**, the host adapter C does not perform the journal replication processing in step **2400** (step **2330**).

(4) The host adapter C checks the update number included in the remote write command and if the update number is a valid value (a value other than "0"), the host adapter C checks the volume state of the journal logical volume. If the volume state of the journal logical volume is "abnormal," which indicates that journals cannot be stored in the journal logical volume, the host adapter C does not perform the journal replication processing in step **2400** (step **2340**).

(5) If the volume state of the journal logical volume is found through checking in step **2340** to be "normal," the host adapter C performs the journal replication processing **2400** described later.

(6) The host adapter C commands one of the disk adapters **120** to write the write data in the storage area of the storage device **150** that corresponds to the logical address in the remote write command, and reports to the primary storage system A that the processing has ended (steps **2360, 2370**). Subsequently, the disk adapter **120** stores the write data in the storage area through the read/write processing.

Next, the journal replication processing **2400** will be described.

(1) The host adapter C checks whether a journal can be stored in the journal logical volume. The host adapter C uses the pointer information **700** to check whether there are any blank areas in the update information area (step **2410**). If the update information latest address and the update information oldest address in the pointer information **700** are equal, which indicates that there are no blank areas in the update information area, the host adapter C frees the storage area of the oldest journal and reserves an update information area (step **2415**). Next, the host adapter C uses the pointer information **700** to check whether the write data can be stored in the write data area (step **2420**). If the write data oldest address is within a range of the write data latest address and a numerical value resulting from adding the data amount A to the write data latest address, which indicates that the write data cannot be stored in the write data area, the host adapter C frees the journal storage area of the oldest journal and makes it possible to store the write data (step **2425**).

(2) The host adapter C creates update information in at least one cache memory **130**. The update time in the remote write command is set as the time the write command for the update information was received. The group number that a pair with a synchronous pair number in the logical volume C belongs to is set as the group number. The update number in the remote write command is set as the update number. The logical address in the remote write command is set as the logical address of the write command. The data size A in the remote write command is set as the data size of the write data. The logical address of the journal logical volume for storing write data is the write data latest address in the pointer information **700**, and a numerical value resulting from adding the size of the write data to the write data latest address is set as the write data latest address in the pointer information **700**. The logical address for storing the update information is the update information latest address in the pointer information **700**, and a numerical value resulting from adding the size of the update information to the update information latest address is set as the update information latest address in the pointer information **700** (step **2430**).

(3) The host adapter C commands one of the disk adapters **120** to write the update information and write data to at least one storage device **150**, and ends the processing as a successful journal creation (step **2440**). Subsequently, the disk

adapter **120** writes the update information and the write data to the storage device **150** through the read/write processing and frees the cache memory **130**.

In this way, the secondary storage system C frees storage areas of old journals and constantly maintains a plurality of new journals.

The read/write processing **220** is a processing that the disk adapters **120** implement upon receiving a command from the host adapters **110** or the disk adapters **120**. The processing implemented are a processing to write data in the designated cache memory **130** to a storage area in the storage device **150** that corresponds to the designated logical address, and a processing to read data to the designated cache memory **130** from a storage area in the storage device **150** that corresponds to the designated logical address.

FIG. **14** is a diagram illustrating the operation (a journal read reception processing) by a host adapter A of the primary storage system **100A** upon receiving a journal read command, and FIG. **15** is a flowchart of the operation. Below, these drawings are used to describe the operation that takes place when the primary storage system **100A** receives a journal read command from the secondary storage system **100B**.

(1) The host adapter A in the primary storage system **100A** receives an access command from the secondary system **100 B**. The access command includes an identifier indicating that the command is a journal read command, a group number that is the subject of the command, and whether there is a retry instruction. In the following, the group number within the access command shall be called a group number A (step **1220** **1410** in FIG. **14**).

(2) The host adapter A checks whether the group state of the group number A is “normal” (step **1510**). If the group state is found through checking in step **1510** to be other than “normal,” such as “abnormal,” the host adapter A notifies the secondary storage system **100 B** of the group state and terminates the processing. The secondary storage system **100B** performs processing according to the group state received. For example, if the group state is “abnormal,” the secondary storage system **100 B** terminates the journal read processing (step **1515**).

(3) If the group state of the group number A is found through checking in step **1510** to be “normal,” the host adapter A checks the state of the journal logical volume (step **1520**). If the volume state of the journal logical volume is found through checking in step **1520** not to be “normal,” such as “abnormal,” the host adapter A changes the group state to “abnormal,” notifies the secondary storage system **100B** of the group state, and terminates the processing. The secondary storage system **100B** performs processing according to the group state received. For example, if the group state is “abnormal,” the secondary storage system **100B** terminates the journal read processing (step **1525**).

(4) If the volume state of the journal logical volume is found through checking in step **1520** to be “normal,” the host adapter A checks whether the journal read command is a retry instruction (step **1530**).

(5) If the journal read command is found through checking in step **1530** to be a retry instruction, the host adapter A re-sends to the secondary storage system **100B** the journal it had sent previously. The host adapter A reserves at least one cache memory **130** and commands one of the disk adapters **120** to read to the cache memory **130** information concerning the size of update information beginning at the retry head address in the pointer information **700** (**1420** in FIG. **14**).

In the read/write processing, the disk adapter **120** reads the update information from at least one storage device **150**,

stores the update information in the cache memory **130**, and notifies of it to the host adapter A (**1430** in FIG. **14**).

The host adapter A receives the notice of the end of the update information reading, obtains the write data logical address and write data size from the update information, reserves at least one cache memory **130**, and commands the disk adapter **120** to read the write data to the cache memory **130** (step **1540** **1440** in FIG. **14**).

In the read/write processing, the disk adapter **120** reads the write data from the storage device **150**, stores the write data in the cache memory **130**, and notifies of it to the host adapter A (**1450** in FIG. **14**).

The host adapter A receives the notice of the end of write data reading, sends the update information and write data to the secondary storage system **100B**, frees the cache memory **130** that has the journal, and terminates the processing (step **1545** **1460** in FIG. **14**).

(6) If the journal read command is found through checking in step **1530** not to be a retry instruction, the host adapter A checks whether there is any journal that has not been sent; if there is such a journal, the host adapter A sends the journal to the secondary storage system **100 B**. The host adapter A compares the read head address to the update information latest address in the pointer information **700** (step **1550**).

If the read head address and the update information latest address are equal, which indicates that all journals have been sent to the secondary storage system **100B**, the host adapter A sends “no journals” to the secondary storage system **100B** (step **1560**) and frees the storage area of the journal that was sent to the secondary storage system **100B** when the previous journal read command was processed (step **1590**).

In the freeing processing of the journal storage area, a retry head address is set as the update information oldest address in the pointer information **700**. If the update information oldest address becomes the write data area head address, the update information oldest address is set to 0. The write data oldest address in the pointer information **700** is changed to a numerical value resulting from adding to the write data oldest address the size of the write data sent in response to the previous journal read command. If the write data oldest address becomes a logical address in excess of the capacity of the journal logical volume, the write data area head address is assigned a lower position and corrected.

(7) If an unsent journal is found through checking in step **1550**, the host adapter A reserves at least one cache memory **130** and commands one of the disk adapters **120** to read to the cache memory **130** information concerning the size of update information beginning at the read head address in the pointer information **700** (**1420** in FIG. **14**).

In the read/write processing, the disk adapter **120** reads the update information from at least one storage device **150**, stores the update information in the cache memory **130**, and notifies of it to the host adapter A (**1430** in FIG. **14**).

The host adapter A receives the notice of the end of the update information reading, obtains the write data logical address and write data size from the update information, reserves at least one cache memory **130**, and commands the disk adapter **120** to read the write data to the cache memory **130** (step **1570** **1440** in **14**).

In the read/write processing, the disk adapter **120** reads the write data from the storage device **150**, stores the write data in the cache memory **130**, and notifies of it to the host adapter A (**1450** in FIG. **14**).

The host adapter A receives the notice of the end of the write data reading, sends the update information and write data to the secondary storage system **100B** (step **1580**) and frees the cache memory **130** that has the journal (**1460** in FIG.

14). The host adapter A then sets the read head address as the retry head address, and a numerical value resulting from adding the update information size of the journal sent to the read head address as the new read head address, in the pointer information 700.

(8) The host adapter A frees the storage area of the journal that was sent to the secondary storage system 100B when the previous journal read command was processed (step 1590).

Although the primary storage system 100A sends journals one at a time to the secondary storage system 100B according to the journal read reception processing described, a plurality of journals may be sent simultaneously to the secondary storage system 100B. The number of journals to be sent in one journal read command can be designated in the journal read command by the secondary storage system 100B, or the user can designate the number in the primary storage system 100A or the secondary storage system 100B when registering groups. Furthermore, the number of journals to be sent in one journal read command can be dynamically varied according to the transfer capability of or load on the connection paths 200 between the primary storage system 100A and the secondary storage system 100B. Moreover, instead of designating the number of journals to be sent, the amount of journals to be transferred may be designated upon taking into consideration the size of journal write data.

Although journals are read from at least one storage device 150 to at least one cache memory 130 according to the journal read reception processing described, this processing is unnecessary if the journals are already in the cache memory 130.

Although the freeing processing of journal storage area in the journal read reception processing described is to take place during the processing of the next journal read command, the storage area can be freed immediately after the journal is sent to the secondary storage system 100 B. Alternatively, the secondary storage system 100B can set in the journal read command an update number that may be freed, and the primary storage system 100A can free the journal storage area according to the instruction.

FIG. 16 is a diagram illustrating the journal read processing 240, FIG. 17 is the flowchart of it, and FIG. 18 is a flowchart of a journal store processing. Below, an operation by a host adapter B of the secondary storage system 100B to read journals from the primary storage system 100A and store the journals in a journal logical volume is described below using these drawings.

(1) If the group state is “normal” and the replication type is asynchronous, the host adapter B in the secondary storage system 100B reserves at least one cache memory 130 for storing a journal, and sends to the primary storage system 100A an access command that includes an identifier indicating that the command is a journal read command, a group number of the primary storage system 100A that is the subject of the command, and whether there is a retry instruction. Hereinafter, the group number in the access command shall be called a group number A (step 1700, 1610 in FIG. 16).

(2) The host adapter B receives a response and a journal from the primary storage system 100A (1620 in FIG. 16).

(3) The host adapter B checks the response; if the response from the primary storage system 100A is “no journals,” which indicates that there are no journals that belong to the designated group in the primary storage system 100A, the host adapter B sends a journal read command to the primary storage system 100A after a predetermined amount of time (steps 1720, 1725).

(4) If the response from the primary storage system 100 A is “the group state is abnormal” or “the group state is blank,” the host adapter B changes the group state of the secondary

storage system 100B to the state received and terminates the journal read processing (steps 1730, 1735).

(5) If the response from the primary storage system 100 A is other than those described above, i.e., if the response is that the group state is “normal,” the host adapter B checks the volume state of the corresponding journal logical volume (step 1740). If the volume state of the journal logical volume is “abnormal,” which indicates that journals cannot be stored in the journal logical volume, the host adapter B changes the group state to “abnormal” and terminates the processing (step 1745). In this case, the host adapter B converts the journal logical volume to a normal logical volume and returns the group state to normal.

(6) If the volume state of the journal logical volume is found through checking in step 1740 to be “normal,” the host adapter B performs a journal store processing 1800 described later. If the journal store processing 1800 ends normally, the host adapter B sends the next journal read command. Alternatively, the host adapter B can send the next journal read command after a predetermined amount of time has passed (step 1700). The timing for sending the next journal command can be a periodic transmission based on a predetermined interval, or it can be determined based on the number of journals received, the communication traffic volume on the connection paths 200, the storage capacity for journals that the secondary storage system 100B has, or on the load on the secondary storage system 100B. The timing can also be determined based on the storage capacity for journals that the primary storage system 100A has or on a numerical value in the pointer information 700 of the primary storage system 100A as read from the secondary storage system 100B. The transfer of the information can be done through a dedicated command or as part of a response to a journal read command. The subsequent processing is the same as the processing that follows step 1700.

(7) If the journal store processing in step 1800 does not end normally, which indicates that there are insufficient blank areas in the journal logical volume, the host adapter B cancels the journal received and sends a journal read command in a retry instruction after a predetermined amount of time (step 1755). Alternatively, the host adapter B can retain the journal in the cache memory 130 and perform the journal store processing again after a predetermined amount of time. This is due to the fact that there is a possibility that there would be more blank areas in the journal logical volume after a predetermined amount of time as a result of a restore processing 250, described later. If this method is used, it is unnecessary to indicate whether there is a retry instruction in the journal read command.

Next, the journal store processing 1800 shown in FIG. 18 will be described.

(1) The host adapter B checks whether a journal can be stored in the journal logical volume. The host adapter B uses the pointer information 700 to check whether there are any blank areas in the update information area (step 1810). If the update information latest address and the update information oldest address in the pointer information 700 are equal, which indicates that there are no blank areas in the update information area, the host adapter B terminates the processing due to a failure to create a journal (step 1820).

(2) If blank areas are found in the update information area through checking in step 1810, the host adapter B uses the pointer information 700 to check whether the write data can be stored in the write data area (step 1830). If the write data oldest address falls within a range of the write data latest address and a numerical value resulting from adding the data amount A to the write data latest address, the write data cannot

be stored in the write data area; consequently, the host adapter B terminates the processing due to a failure to create a journal (step 1820).

(3) If the journal can be stored, the host adapter B changes the group number and the logical address of the journal logical volume for storing write data of the update information received. The group number is changed to the group number of the secondary storage system 100B, and the logical address of the journal logical volume is changed to the write data latest address in the pointer information 700. Furthermore, the host adapter B changes the update information latest address to a numerical value resulting from adding the size of the update information to the update information latest address, and the write data latest address to a numerical value resulting from adding the size of the write data to the write data latest address, in the pointer information 700. Moreover, the host adapter B changes the update number in the group information 600 to the update number of the update information received (step 1840).

(4) The host adapter B commands one of the disk adapters 120 to write the update information and write data to at least one storage device 150, and ends the processing as a successful journal creation (step 1850 1630 in FIG. 16). Subsequently, the disk adapter 120 writes the update information and the write data to the storage device 150 through the read/write processing and frees the cache memory 130 (1640 in FIG. 16).

Although the journals are stored in the storage devices 150 according to the journal creation processing described, the cache memory 130 having a predetermined amount of memory for journals can be prepared in advance and the cache memory 130 can be used fully before the journals are stored in the storage device 150. The amount of cache memory for journals can be designated through the maintenance terminal, for example.

FIG. 19 is a diagram illustrating the restore processing 250, and FIG. 20 is a flowchart of it. Below, an operation by the host adapter B of the secondary storage system 100B to utilize journals in order to update data is described below using these drawings. The restore processing 250 can be performed by one of the disk adapters 120 of the secondary storage system 100B.

(1) The host adapter B checks if the group state of the group number B is “normal” or “halted” (step 2010). If the group state is found through checking in step 2010 to be other than “normal” or “halted,” such as “abnormal,” the host adapter B terminates the restore processing (step 2015).

(2) If the group state is found through checking in step 2010 to be “normal” or “halted,” the host adapter B checks the volume state of the corresponding journal logical volume (step 2020). If the volume state of the journal logical volume is found through checking in step 2020 to be “abnormal,” which indicates that the journal logical volume cannot be accessed, the host adapter B changes the group state to “abnormal” and terminates the processing (step 2025).

(3) If the volume state of the journal logical volume is found to be “normal” through checking in step 2020, the host adapter B checks whether there is any journal that is the subject of restore. The host adapter B obtains the update information oldest address and the update information latest address in the pointer information 700. If the update information oldest address and the update information latest address are equal, there are no journals that are the subject of restore; consequently, the host adapter B terminates the restore processing for the time being and resumes the restore processing after a predetermined amount of time (step 2030).

(4) If a journal that is the subject of restore is found through checking in step 2030, the host adapter B performs the following processing on the journal with the oldest (i.e., smallest) update number. The update information for the journal with the oldest (smallest) update number is stored beginning at the update information oldest address in the pointer information 700. The host adapter B reserves at least one cache memory 130 and commands one of the disk adapters 120 to read to the cache memory 130 information concerning the size of update information from the update information oldest address (1910 in FIG. 19).

In the read/write processing, the disk adapter 120 reads the update information from at least one storage device 150, stores the update information in the cache memory 130, and notifies of it to the host adapter B (1920 in FIG. 19).

The host adapter B receives the notice of the end of the update information reading, obtains the write data logical address and write data size from the update information, reserves at least one cache memory 130, and commands the disk adapter 120 to read the write data to the cache memory 130 (1930 in FIG. 19).

In the read/write processing, the disk adapter 120 reads the write data from the storage device 150, stores the write data in the cache memory 130, and notifies of it to the host adapter B (step 2040 1940 in FIG. 19).

(5) The host adapter B finds from the update information the logical address of the secondary logical volume to be updated, and commands one of the disk adapters 120 to write the write data to the secondary logical volume (step 2050 1950 in FIG. 19). In the read/write processing, the disk adapter 120 writes the data to the storage device 150 that corresponds to the logical address of the secondary logical volume, frees the cache memory 130, and notifies of it to the host adapter B (1960 in FIG. 19).

(6) The host adapter B receives the notice of write processing completion from the disk adapter 120 and frees the storage area for the journal. In the freeing processing of the journal storage area, the update information oldest address in the pointer information 700 is changed to a numerical value resulting from adding the size of the update information thereto. If the update information oldest address becomes the write data area head address, the update information oldest address is set to 0. The write data oldest address in the pointer information 700 is changed to a numerical value resulting from adding the size of the write data to the write data oldest address. If the write data oldest address becomes a logical address in excess of the capacity of the journal logical volume, the write data area head address is assigned a lower position and corrected. The host adapter B then begins the next restore processing (step 2060).

Although journals are read from at least one storage device 150 to at least one cache memory 130 in the restore processing 250, this processing is unnecessary if the journals are already in the cache memories 130.

Although the primary storage system 100A determines which journals to send based on the pointer information 700 in the journal read reception processing and the journal read processing 240 described, the journals to be sent may instead be determined by the secondary storage system 100B. For example, an update number can be added to the journal read command. In this case, in order to find the logical address of the update information with the update number designated by the secondary storage system 100B in the journal read reception processing, a table or a search method for finding a logical address storing the update information based on the update number can be provided in the shared memories 140 of the primary storage system 100A.

Although the journal read command is used in the journal read reception processing and the journal read processing 240 described, a normal read command may be used instead. For example, the group information 600 and the pointer information 700 for the primary storage system 100A can be transferred to the secondary storage system 100B in advance, and the secondary storage system 100B can read data in the journal logical volume (i.e., journals) of the primary storage system 100A.

Although journals have been described as being sent from the primary storage system 100A to the secondary storage system 100B in the order of update numbers in the journal read reception processing, the journals do not have to be sent in the order of update numbers. Furthermore, a plurality of journal read commands may be sent from the primary storage system 100A to the secondary storage system 100B. In this case, in order to process journals in the order of update numbers in the restore processing, a table or a search method for finding a logical address storing update information based on each update number is provided in the secondary storage system 100B.

In the computer system of the present invention, the storage system A stores information on data update as a journal. The storage system B has a replication of data that the storage system A has; the storage system B obtains journals from the storage system A in an autonomic manner and uses the journals to update its data that correspond to data of the storage system A in the order of data update in the storage system A. Through this, the storage system B can replicate data of the storage system A, while maintaining data integrity. Furthermore, management information for managing journals does not rely on the capacity of data that is the subject of replication.

The procedure for using a host computer 180C and the storage system 100C to resume the information processing performed by the host computer 180 and to resume data replication on the storage system 100B in the event the primary storage system 100A fails is shown in 25; a block diagram of the logical configuration of the procedure is shown in 42. The host computer 180 and the host computer 180C may be the same computer.

In the following description, FIG. 4 shows the volume information, FIG. 5 shows the pair information, FIG. 6 shows the group information, FIG. 7 shows the pointer information, and FIG. 8 shows a diagram illustrating the pointer information of the primary storage system 100A before it fails. FIG. 26 shows the volume information, FIG. 27 shows the pair information, FIG. 28 shows the group information, FIG. 29 shows the pointer information, and FIG. 30 shows a diagram illustrating the pointer information of the secondary storage system 100B (asynchronous replication) before the primary storage system 100A fails. Since the secondary storage system 100B performs asynchronous data replication, it may not have all the journals that the primary storage system 100A has (update numbers 3-5). In the present example, the secondary storage system 100B does not have the journal for the update number 5. FIG. 31 shows the volume information, FIG. 32 shows the pair information, FIG. 33 shows the group information, FIG. 34 shows the pointer information, and FIG. 35 shows a diagram illustrating the pointer information of the secondary storage system 100C (synchronous replication) before the primary storage system 100A fails. Since the secondary storage system 100C performs synchronous data replication, it has all the journals (update numbers 3-5) that the primary storage system 100A has.

(1) A failure occurs in the primary storage system 100 A and the primary logical volumes (DATA 1, DATA 2) become unusable (step 2500).

(2) The host computer 180 issues a delta-resync command to the storage system 100C. The delta-resync command is a command for changing an asynchronous data replication source (primary logical volume) in a group unit, and includes replication source information and replication destination information. The replication source information indicates the storage system number C and group number D having secondary logical volumes (data1, data2) of synchronous data replications. The replication destination information indicates the storage system number B and group number B having secondary logical volumes (COPY1, COPY2) of asynchronous data replications. Both the group numbers D and B have the delta reservation option of "1" (step 2510).

(3) Upon receiving the delta-resync command, the storage system 100C refers to the volume information, pair information and group information of the storage systems 100B and 100C, and changes the pair state of the logical volumes belonging to the group C corresponding to asynchronous remote copies already existing in the storage system 100C, from "normal" to "delta-processing". The storage system also changes the pair state of the logical volumes belonging to the group D in the storage system 100C, from "delta-ready" to "normal". The storage system 100C further changes the group information in such a manner that the group D can continuously use the journal logical volumes belonging to the group C. Specifically, the storage system 100C changes the update number of the group D to the update number of the group C, changes the journal logical volume number of the group D to the journal logical volume number of the group C, and sets all items of the pointer information of the group D same as those of the pointer information of the group C. In response to the delta-sync command, the storage system 100C changes the pair information of the storage system 100C shown in FIG. 32 to the pair information shown in FIG. 39, changes the group information of the storage system 100C shown in FIG. 33 to the group information shown in FIG. 40, and changes the volume information of the storage system 100C shown in FIG. 31 to the volume information shown in FIG. 38.

The storage system 100C changes the pair state of the logical volumes belonging to the group C in the storage system 100C from "normal" to "delta-processing" for the storage system 100B. Similarly, the pair state of the logical volumes belonging to the group D in the storage system 100C is changed from "delta-ready" to "normal".

The storage system 100B refers to the volume information, pair information and group information of the storage system 100B and the storage system 100C and makes changes to the pair information and group information of the storage system 100B. By changing the pair information for the group B shown in FIG. 27 to the pair information shown in FIG. 36, the group information shown in FIG. 28 to the group information shown in FIG. 37, and the state of the group information for the group B to "halted," the storage system 100B halts the journal read processing to the storage system 100A (steps 2530, 2540).

(4) The storage system 100C sends a response to the delta-resync command to the host computer 180 or a maintenance terminal. Upon receiving the response to the delta-resync command from the storage system 100C, the host computer recognizes a completion of delta-resync and start using the storage system 100C (steps 2550, 2560).

(5) The storage system 100B sends a journal read position designation command to the storage system 100C (step

2570). The journal read position designation command is a command to change the pointer information of the group D of the storage system 100C and to designate a journal that is sent based on a journal read command from the storage system 100 B; the journal read position designation command includes a partner group number D and an update number B. The partner group number D designates the partner group number for the group number B. The update number designates a numerical value resulting from adding 1 to the update number in the group information for the group number B. In the example shown in FIG. 37, the partner group number 2 and the update number 5 are designated.

(6) Upon receiving the journal read position designation command, the storage system 100C refers to the pointer information 700 and checks whether there is a journal for the update number B. The storage system 100C reads the update information of the update information oldest address in the pointer information from at least one storage device 150 and obtains the oldest (smallest) update number C.

If the update number C is equal to or less than the update number B in the journal read position designation command, which indicates that the storage system 100C has the journal for the update number B, the storage system 100B can continue with the asynchronous data replication. In this case, the storage system 100 C frees storage areas for journals that precede the update number B, changes the read head address and the retry head address to addresses for storing the update information for the update number B, and sends “resumption possible” to the storage system 100B. Through this, the pointer information shown in FIG. 34 is changed to the pointer information shown in FIG. 41 (step 2580).

On the other hand, if the update number C is greater than the update number B in the journal read position designation command, which indicates that the storage system 100B does not have the journal required by the storage system 100C, the storage system 100B cannot continue the asynchronous data replication. In this case, data replication must be initiated based on the procedures described using S. 9 and 10 from the primary storage system 100 C to the secondary storage system 100B.

(7) Upon receiving the “resumption possible” response, the storage system 100B resumes a journal read processing to the storage system 100C by changing the state of the group information for the group B to “normal” (step 2590).

The storage system 100B does not have to issue a journal read position designation command. In this case, the storage system 100B initiates a journal read processing and receives the oldest journal from the storage system 100C. If the update number C of the journal received is greater than a numerical value resulting from adding 1 to the update number in the group information for the group number B (the update number B), which indicates that the storage system 100C does not have the journal required by the storage system 100B, the storage system 100 B halts the data replication process. If the update number C of the journal received is less than the update number B, which indicates that the storage system 100B already has the journal, the storage system B cancels the journal and continues the journal read processing. If the update number C of the journal received is equal to the update number B, the storage system B stores the journal received in the journal logical volume and continues the journal read processing.

An operation to reflect data update to the primary logical volume (data 1) of the primary storage system 100C on the secondary logical volume (COPY 1) of the secondary storage system 100B after the host computer 180C begins to use the storage system 100C is generally described using FIG. 42.

(1) Upon receiving a write command from the host computer 180C for data in the primary logical volume (data 1), the primary storage system 100C updates data in the primary logical volume (data 1) and stores journals in the journal logical volume (jnl 1) through the command reception processing 210 and the read/write processing 220, and reports the end of the write command to the host computer 180C (4200 in FIG. 42).

(2) The secondary storage system 100B reads journals from the primary storage system 100C through the journal read processing 240 and stores the journals in the journal logical volume (JNL 2) through the read/write processing 220 (4210 in FIG. 42).

(3) Upon receiving a journal read command from the secondary storage system 100B, the primary storage system 100C reads the journals from the journal logical volume (jnl 1) and sends the journals to the secondary storage system 100B through the command reception processing 210 and the read/write processing 220 (4210 in FIG. 42).

(4) The secondary storage system 100B uses the pointer information 700 through the restore processing 250 and the read/write processing 220 to read the journals from the journal logical volume (JNL 2) in ascending order of update numbers and updates data in the secondary logical volume (COPY 1) (4220 in FIG. 42). As a result, data in the primary logical volume (data 1) in the primary storage system 100 C and data in the secondary logical volume (COPY 1) in the secondary storage system 100B match completely some time after the update of the primary logical volume.

Next, with reference to FIG. 43, description will be made on a delta recovery process 2600 which is a recovery means after the pair state for delta-resync transits to “abnormal delta” because of a failure such as a failure of the journal logical volume and disconnection of the connection path 200 between the storage systems C and B, after the group and pair for delta-resync are generated.

After detecting the pair state of “abnormal delta”, a user removes the failure at first. Thereafter, the host computer 180 issues a delta recovery process command. The delta recovery process command includes a designation subject group ID, a partner storage system number B and a partner group number B.

First, the secondary storage system 100C resumes the journal replication process for the group number C corresponding to the logical volume of the designation subject group number D (step 2610).

Next, the secondary storage system 100C changes the pair state of the logical volumes of the group number D with “abnormal delta”, to “delta-processing” (step 2620).

Next, similar to the above-described delta reservation process, the secondary storage system 100C checks whether delta-resync is possible (step 2630). Namely, the secondary storage system 100C judges from the following comparison procedure whether replication subjects of two groups having the pair registered for delta-resync as their replication destinations are coincident and also the pair numbers are coincident.

The secondary storage system 100C extracts pair information having the same secondary storage system number and secondary logical volume number as the primary storage system number C and primary logical volume number C of the pair having the designated group number D, from the pair information 500, and acquires a primary storage system number A2 and a primary logical volume number A1 from the extracted pair information (step 4630). Next, the secondary storage system 100C acquires, from the secondary storage system 100B having the secondary logical storage system

number B corresponding to the primary system number C and primary logical volume number C, the primary storage system number A2 and primary logical volume number A1 of a pair having as a replication destination the secondary storage system number B and secondary logical volume number B corresponding to the primary storage system number C and primary logical volume number C and having the delta reservation option of not "1" (step 4640). The secondary storage system 100C judges whether the acquired primary storage system number A1 and primary logical volume number A1 are coincident with the primary storage system number A2 and primary logical volume number A2 (step 4650). This judgment is performed for all pairs having the designated group number C at a loop from step 4620 to step 4660).

If this judgment indicates incoincidence, the secondary storage system 100C terminates the process as an error.

Next, the secondary storage system 100C judges through comparison whether the journal data is transferred which is necessary for delta-resync.

First, the secondary storage system 100C acquires, from the secondary storage system 100B having the partner storage system number B written in the group number having the designated group number D and the delta reservation option of "1", in the group information 600, a numerical value B1 obtained by adding "1" to an update number B of the group having the partner group number B written in the group number (step 4672). Next, the storage system 100C refers to the pointer information 700 to check whether it has the journal of the update number B. The storage system 100C reads update information of an update information oldest address of the pointer information from the storage device 150 to obtain the oldest (smallest) update number C (step 4674). The storage system C compares the update number C with the acquired update number B1 (step 4676), and if the update number C is equal to or smaller than the update number B1, it means that the storage system has the journal of the update number B, so that it is judged that delta-resync is possible (step 4678).

If it is judged that delta-resync is possible, the pair state of the pair information 500 having the group number is changed to "delta-ready" to terminate the process.

In the process described above, a command from the host computer 180 to the storage system is issued upon an input event of a user operation via a user interface provided by the storage management program. This configuration will be described with reference to FIG. 44. With reference to FIG. 44, although description will be made by using the computer system 100A and the host computer 180 connected thereto, the description is also applied to the storage systems 100B and 100C.

A host computer 180 is constituted of a CPU 180-1, a main storage device 180-2, an interface (I/F) 180-3, and a management I/F 180-4. A host computer service processor (SVP) 180-5 is connected to the host computer 180.

CPU 180-1 is a processor for the host computer 180. Namely, CPU 180-1 reads and executes OS, programs and the like stored in the main storage device 180-2 to perform various processes defined by OS and programs.

The main storage device 180-2 is a memory such as DRAM. The main storage device 180-2 stores an OS 180-6 and a storage management program 180-7.

OS 180-6 is an operating system for the host computer 180. As OS 180-6 is executed by CPU 180-1, the host computer 180 performs fundamental operations.

The storage management program 180-7 issues a control command to the computer system 100 to manage a storage

system 100, and is a program for supplying a user interface, this program being read and executed by CPU 180-1.

I/F 180-3 is an interface for data transfer relative to the storage system 100.

A host computer SVP 180-5 is an input/output control terminal for issuing a command such as a maintenance command to the host computer 180 in accordance with an instruction by a manager. The host computer 180 has the management I/F 180-4 which is an interface for data transfer relative to the host computer SVP 180-5.

The storage management program 180-7 performs storage management including pair generation and state information display for delta-resync described in the embodiment.

A command reception process 210 performs a command reception process including a pair reservation process and pair state management for delta-resync described in the embodiment.

Pair information 600 includes state information of a reservation pair for delta-resync described in the embodiment. The details of the pair information 500 are shown, for example, in FIGS. 5, 27 and 32.

Group information 600 includes option information of a reservation pair for delta-resync described in the embodiment. The details of the group information 600 are shown, for example, in FIGS. 6, 28 and 33.

The host computer 180 may have a graphical user interface (GUI) for facilitating user data input. For example, GUI displays the storage systems 100A, 100B and 100C connected to the host computer 180, on the host computer SVP 180-5 by using the connection topology thereof. Upon receiving an instruction from a user, GUI may generate management command information for remote copy pairs in the storage systems 100A, 100B and 100C, to supply the information to the storage management program 180-7. GUI may visually display pairs including delta-resync pairs and group information of the storage systems 100A, 100B and 100C, on the host computer SVP 180-5. In this manner, a user can select each pair and group by using GUI interface, and can easily instruct a delta-resync operation to the host computer 180. Pair information for delta-resync between the storage systems 100B and 100C may be identified by referring to pair information between the storage systems 100A and 100B and between the storage systems 100A and 100C. In this case, error occurrence in the delta reservation process can be reduced. An example of GUI is shown in FIG. 45.

In the computer system of the above-described embodiment, the computer system C generates a journal by using the update number and update time of the computer system S. If the storage system A, which is the subject of data replication, fails and information processing is continued using the storage system C, the storage system B changes the journal acquisition source from the storage system A to the storage system C. As a result, the storage system B can continue to replicate data of the storage system A, while maintaining data integrity. Furthermore, management information for managing journals does not rely on the capacity of data that is the subject of replication.

In the above-described computer system of the present invention, the pair state for delta-resync is displayed to a user by using three states including "delta-ready" able to perform delta-resync, "abnormal delta" such as a failure requiring a user operation, and "delta-processing" unable to perform delta-resync such as during a delta-resync pair registration process and during a recovery process from "abnormal delta". A user is provided with a delta reservation procedure of registering delta-resync pairs as dedicated pairs before the delta-resync is performed. A user is also provided with a delta

recovery procedure for indicating a pair state transition from “delta-processing” and “abnormal delta” to “delta-ready”. A user can therefore manage delta-resync pairs before delta-resync is instructed.

As described so far, according to the computer system of the embodiment, when scheduling is stopped because of a failure or maintenance of the computer system executing business transactions by using the computer system A or storage system A, the business transactions are required to be continued. To this end, data-resync is executed for ensuring data integrity between the storage system C and storage system B by copying data corresponding to difference data therebetween. In this case, data transfer settings between the storage systems C and B can be monitored beforehand by the host computer. It is therefore possible to eliminate the state unable to perform delta-resync. It is therefore possible to elongate the period able to perform delta-resync. Even if a failure occurs in the storage system, the storage system C can perform delta-resync immediately and inherit business transactions. While the description above refers to particular embodiments of the present invention, it will be understood that many modifications may be made without departing from the spirit thereof. The accompanying claims are intended to cover such modifications as should fall within the true scope and spirit of the present invention.

It should be further understood by those skilled in the art that although the foregoing description has been made on embodiments of the invention, the invention is not limited thereto and various changes and modifications may be made without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. A storage system comprising:

a first storage apparatus, coupled to a host computer, including first volumes;

a second storage, coupled to the first storage apparatus, including second volumes and managing first pairs between the first volumes and the second volumes for storing replication data of the first volumes to the second volumes by second remote copy; and

a third storage apparatus, coupled to the first storage apparatus, including third volumes and managing second pairs between the first volumes and the third volumes for storing replication data of the first volumes to the third volumes by first remote copy,

wherein the third storage apparatus stores difference data between the third volumes and the second volumes, which is used to start a first remote copy of differential pairs between the third volumes to the second volumes, wherein the third storage apparatus stores differential pair statuses of the differential pairs,

wherein normal statuses of the differential pair statuses indicate that the third storage apparatus and the second storage apparatus are replicating data between the second volumes and the third volumes by the first remote copy of the differential pairs,

wherein ready statuses of the differential pair statuses indicate that the third storage apparatus and the second storage apparatus are ready for starting the first remote copy of the differential pairs,

wherein abnormal statuses of the differential pair statuses indicate that the third storage apparatus and the second storage apparatus are not ready for starting the first remote copy of the differential pair, and

wherein according to changing the differential pair statuses from the abnormal statuses to the ready statuses, the first storage apparatus and the second storage apparatus and

the third storage apparatus count a number of the first volumes, a number of the second volumes and a number of the third volumes, for checking the numbers are equal.

2. A storage system according to claim 1, wherein the first storage apparatus manages a first group including the first volumes,

wherein the second storage apparatus manages a second group including the second volumes, and

wherein the third storage apparatus manages a third group including the third volumes.

3. A storage system according to claim 2, wherein the third storage apparatus receives instruction indicating the third group for the changing of the differential pair statuses from the abnormal statuses to the ready statuses.

4. A storage system according to claim 3, wherein for the first remote copy of the first pairs and the second remote copy of the second pairs:

the first storage system creates update numbers indicating write order and, corresponds to write data from the host computer to the update numbers;

the second storage system receives the write data with the update numbers firstly to a reception of the write data by the first storage system, reflects the write data considering to the update numbers, and stores a second update number which indicates a newest update number corresponding to which write data is reflected; and

the second storage system receives the write data with the update numbers secondly to the reception of the write data by the first storage system, reflects the write data, and stores the received write data with the update numbers as the difference data.

5. A storage system according to claim 4, wherein according to changing the differential pair statuses from the abnormal statuses to the ready statuses, the third storage system:

acquires a oldest update number from the write data with the update number stored as the difference data; and compares the second update number and the oldest number.

6. A storage system according to claim 1, wherein the first pair is an asynchronous pair and the second pair is a synchronous pair.

7. A remote copying method for a storage system including a first storage apparatus coupled to a host computer, second storage apparatus, and third storage apparatus, the method comprising:

managing, by the second storage system, first pairs between first volumes included in the first storage apparatus and second volumes included in the second storage apparatus for storing replication data of the first volumes to the second volumes by second remote copy;

managing, by the third storage system, second pairs between the first volumes and third volumes included in the third storage apparatus for storing replication data of the first volumes to the third volumes by first remote copy;

storing, by the third storage apparatus, difference data between the third volumes and the second volumes, which is used to start a first remote copy of differential pairs between the third volumes to the second volumes; and

storing, by the third storage apparatus, differential pair statuses of the differential pairs, wherein normal statuses of the differential pair statuses indicate that the third storage apparatus and the second storage apparatus are replicating data between the second volumes and the third volumes by the first remote copy of the differential pairs,

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wherein ready statuses of the differential pair statuses indicate that the third storage apparatus and the second storage apparatus are ready for starting the first remote copy of the differential pairs,

wherein abnormal statuses of the differential pair statuses indicate that the third storage apparatus and the second storage apparatus are not ready for starting the first remote copy of the differential pair, and

wherein according to changing the differential pair statuses from the abnormal statuses to the ready statuses, the first storage apparatus and the second storage apparatus and the third storage apparatus count a number of the first volumes, a number of the second volumes and a number of the third volumes, for checking the numbers are equal.

8. A remote copy method according to claim 7, wherein the first storage apparatus manages a first group including the first volumes,

wherein the second storage apparatus manages a second group including the second volumes, and

wherein the third storage apparatus manages a third group including the third volumes.

9. A remote copy method according to claim 8, wherein the third storage apparatus receives instruction indicating the third group for the changing of the differential pair statuses from the abnormal statuses to the ready statuses.

10. A remote copy method according to claim 9, wherein for the first remote copy of the first pairs and the second remote copy of the second pairs:

the first storage system creates update numbers indicating write order and, corresponds to write data from the host computer to the update numbers;

the second storage system receives the write data with the update numbers firstly to a reception of the write data by the first storage system, reflects the write data considering to the update numbers, and stores a second update number which indicates a newest update number corresponding to which write data is reflected; and

the second storage system receives the write data with the update numbers secondly to the reception of the write data by the first storage system, reflects the write data, and stores the received write data with the update numbers as the difference data.

11. A remote copy method according to claim 10, wherein according to changing the differential pair statuses from the abnormal statuses to the ready statuses, the third storage system:

acquires a oldest update number from the write data with the update number stored as the difference data; and compares the second update number and the oldest number.

12. A remote copy method according to claim 7, wherein the first pair is an asynchronous pair and the second pair is a synchronous pair.

13. A storage apparatus adapted to be coupled to a first storage apparatus and a second storage apparatus,

wherein the first storage apparatus coupled to a host computer, including first volumes;

wherein the second storage coupled to the first storage apparatus, including second volumes and managing first pairs between the first volumes and the second volumes for storing replication data of the first volumes to the second volumes by second remote copy,

the storage apparatus comprising:

at least one Hard Disk Drive (HDD); and

at least one adapter providing third volumes and managing second pairs between the first volumes and the third

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volumes for storing replication data of the first volumes to the third volumes by first remote copy,

wherein the at least one adapter stores difference data between the third volumes and the second volumes,

which is used to start a first remote copy of differential pairs between the third volumes to the second volumes,

wherein the at least one adapter stores differential pair statuses of the differential pairs,

wherein normal statuses of the differential pair statuses indicate that the third storage apparatus and the second storage apparatus are replicating data between the second volumes and the third volumes by the first remote copy of the differential pairs,

wherein ready statuses of the differential pair statuses indicate that the third storage apparatus and the second storage apparatus are ready for starting the first remote copy of the differential pairs,

wherein abnormal statuses of the differential pair statuses indicate that the third storage apparatus and the second storage apparatus are not ready for starting the first remote copy of the differential pair, and

wherein according to changing the differential pair statuses from the abnormal statuses to the ready statuses, the at least one adapter count a number of the third volumes for checking the number of the third volumes and a number of second volumes are equal.

14. A storage system according to claim 13, wherein the first storage apparatus manages a first group including the first volumes,

wherein the second storage apparatus manages a second group including the second volumes, and

wherein the at least one adapter manages a third group including the third volumes.

15. A storage system according to claim 14, wherein the at least one adapter receives instruction indicating the third group for the changing of the differential pair statuses from the abnormal statuses to the ready statuses.

16. A storage system according to claim 15, wherein for the first remote copy of the first pairs and the second remote copy of the second pairs:

the first storage system creates update numbers indicating write order and, corresponds to write data from the host computer to the update numbers;

the second storage system receives the write data with the update numbers firstly to a reception of the write data by the first storage system, reflects the write data considering to the update numbers, and stores a second update number which indicates a newest update number corresponding to which write data is reflected; and

the second storage system receives the write data with the update numbers secondly to the reception of the write data by the first storage system, reflects the write data, and stores the received write data with the update numbers as the difference data.

17. A storage system according to claim 16, wherein according to changing the differential pair statuses from the abnormal statuses to the ready statuses, the third storage system:

acquires a oldest update number from the write data with the update number stored as the difference data; and compares the second update number and the oldest number.

18. A storage system according to claim 13, wherein the first pair is an asynchronous pair and the second pair is a synchronous pair.